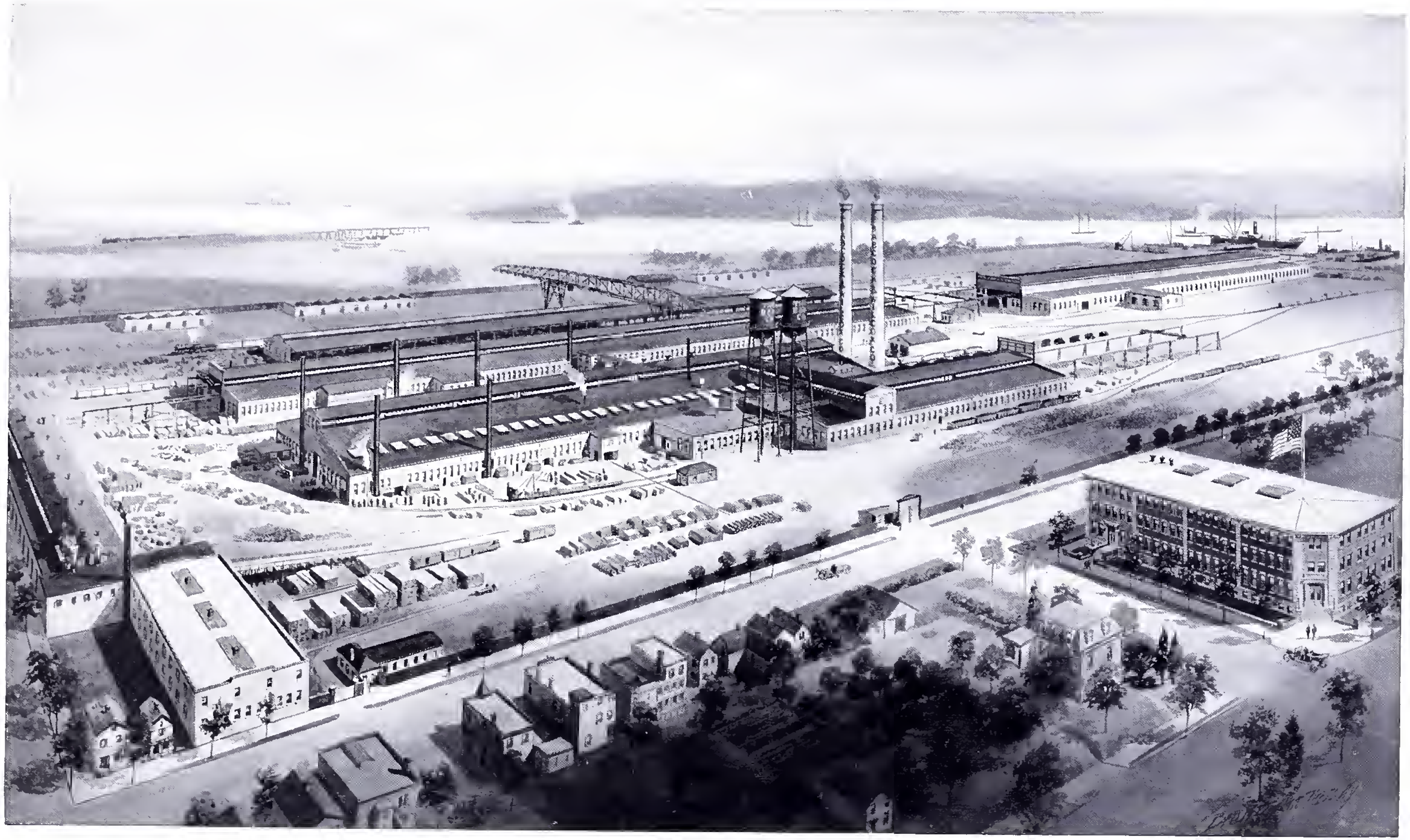
THE STIRLING
WATER-TUBE BOILER

THE
BABCOCK & WILCOX
COMPANY

THE STIRLING
WATER-TUBE BOILER

THE BABCOCK & WILCOX CO.
NEW YORK



WORKS OF THE BABCOCK & WILCOX COMPANY, AT BAYONNE, NEW JERSEY

THE BABCOCK & WILCOX CO.

85 LIBERTY STREET, NEW YORK, U. S. A.

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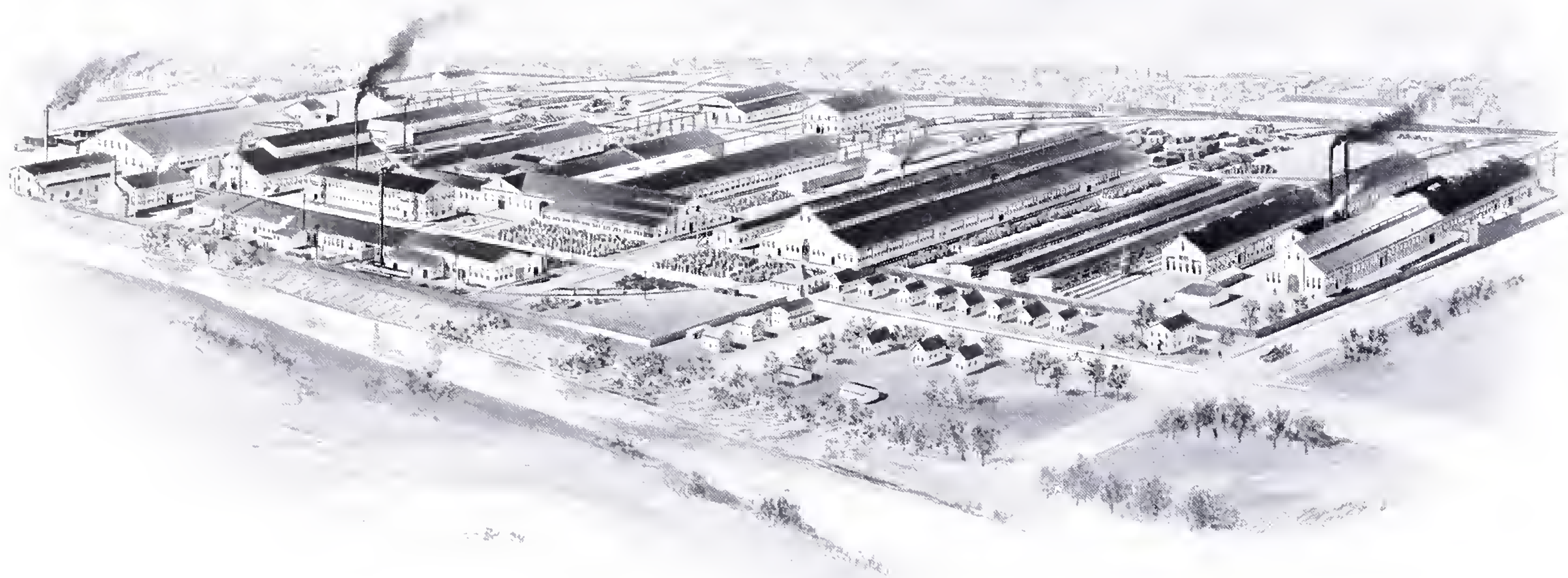


WORKS OF THE BABCOCK & WILCOX COMPANY, AT BARBERTON, OHIO

THE SELECTION OF A BOILER

THE selection of steam boilers is a business and an engineering problem which deserves and should receive the most careful thought. Too frequently the financial aspect of interest and amortization charges on first cost is made the governing factor in the selection of the boilers to be purchased. Though the life of a well-designed, well-built, and properly-operated boiler has yet to be determined, experience has demonstrated that the length of service possible from a boiler of this class is such as to make first cost of immaterial importance as compared with the other factors entering into the problem.

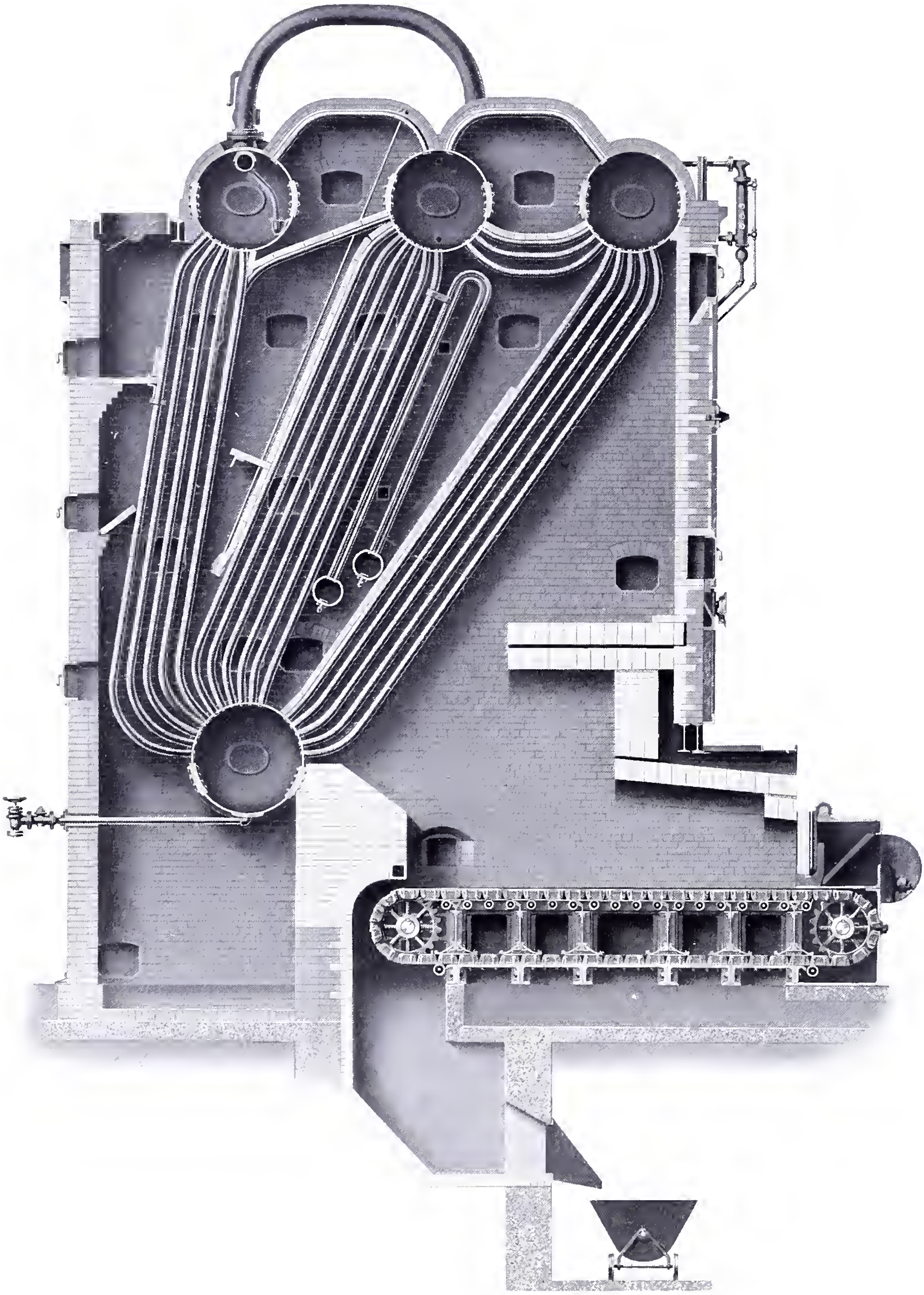
Formerly many purchasers who were inclined to buy the cheapest boiler, with little or no investigation as to the fitness for their needs of the various boilers available, would consider with the greatest of care the relative advantages of various makes of prime movers and auxiliaries. As a result of such practice, a creditable engine-room performance would frequently be nullified by the high operating and upkeep cost and the unreliability of boilers purchased because of low price. The worst feature of such an uneconomical condition was that in many instances the best boiler for the service could have been purchased at a price but little above that actually paid, with a resulting large saving in fuel and maintenance charges over those now paid by the owner. It is not the first cost but the total cost of the production of the necessary amount of steam that is of importance.

Fortunately, since the close of the World War, the importance of sturdy, efficient boilers has received far wider recognition than heretofore, and many power-plant operators have stated in discussions before technical associations that the selection, installation and operation of boilers should receive as much and as careful consideration as is given to the prime movers and generators.

The special requirements of each individual installation must be taken into account before the general type of boiler is selected. The conditions under which the boiler will be called upon to operate and, in certain plants, the class of operators available are important factors in the selection of the proper type. With the type determined, the factors of primary importance are safety, efficiency, reliability, durability, accessibility and the cost of operation and maintenance.

The best guaranty of the safety and continuing reliability of a steam boiler is the reputation of its builder. The Stirling boiler is built by a company which has been building water-tube boilers for more than half a century. The company is assured of the safety of the Stirling boiler by using the most suitable materials for their several purposes in ways which theory and operating experience show to be best. The boilers are built by skilled workmen in shops planned and equipped specially for their manufacture.

Safety is a relative term when applied to boilers: for example, the grade of steel tubes standard for Stirling boilers costs more than that regularly used in



STIRLING BOILER WITH BABCOCK & WILCOX SUPERHEATER AND BABCOCK & WILCOX BLAST CHAIN GRATE STOKER

many competing boilers, except at extra expense, but the use of such tubes increases the safety of the boiler and its freedom from tube troubles. In comparing boiler costs, such extra value should be considered.

The boiler is built in accordance with the Boiler Code of the American Society of Mechanical Engineers and a certificate of shop inspection by the Hartford Steam Boiler Inspection & Insurance Company, or other qualified inspection company, is furnished with each boiler.

The efficiency of the Stirling boiler is shown by the results of tests given elsewhere in this book. These efficiencies, while obtained under test conditions, are being duplicated in numerous plants in daily operation.

The reliability of operation of the Stirling boiler and its freedom from shut-downs for repairs were perhaps best demonstrated during the World War when continuous operation was of paramount importance. In many industries, even in normal times, the money value of dependable continuous performance is an important consideration.

The durability of the Stirling boiler is proven by the thousands of installations which have been giving satisfactory service for many years.

Every part of the Stirling boiler, external and internal, is readily accessible for inspection and repairs.

Under proper operating conditions, the costs of operation and maintenance are functions of the boiler design. These costs are reduced to a minimum in the Stirling boiler because it has been designed to fulfill the requirements for the satisfactory operation of any steam boiler, which may be stated as follows:

1st. The design of the pressure parts must be such as to eliminate the possibility of metal strain under temperature changes. The Stirling boiler is supported independent of the brickwork in such manner as to allow complete freedom for expansion and contraction. Further, the circulation is such that all pressure parts are kept at approximately the same temperature.

2nd. The water and gas passages must be ample. In the Stirling boiler the tube arrangement is such that the gases of combustion have a free passage around each tube and there is no possibility of the gases being unduly throttled or of the spaces between the tubes becoming clogged by deposits of soot. The banks of tubes are so arranged as to allow the installation of a superheater in the most advantageous position in the path of the gases. The circulation is definite and positive, as is explained in detail on pages 53 and 55.

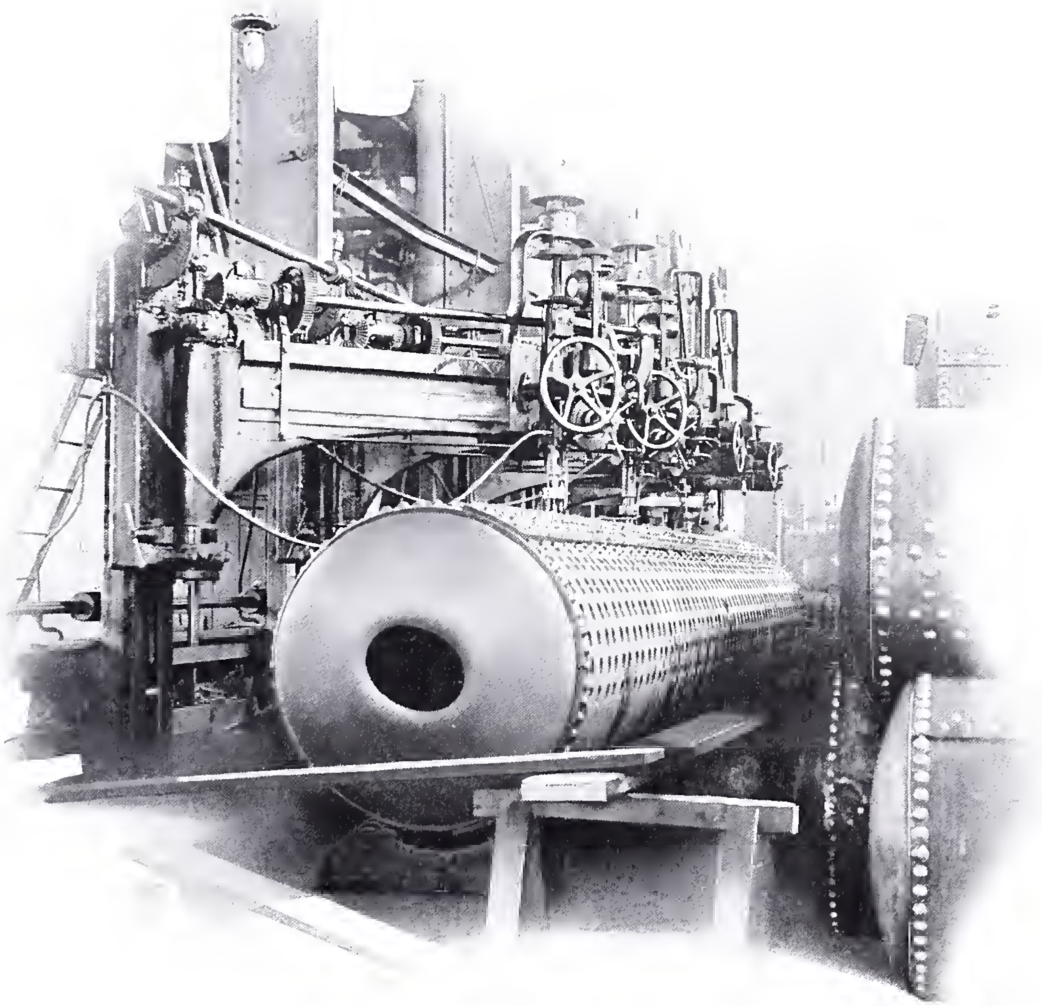
3rd. There should be no possibility of steam or air pockets at points exposed to great heat.

4th. There should be no large flat surfaces. Such surfaces, stayed or unstayed, are among the most objectionable features in boiler design. They are dangerous and should not be used in any boiler carrying the high pressures now common in modern power plants. Such surfaces are frequently located so as to form convenient lodging places for dust and soot, which fuse into a hard mass,

BLACKSTONE HOTEL, CHICAGO, ILL., OPERATING 1012 HORSE POWER OF STIRLING BOILERS

difficult to reach and to remove, and which, because of its non-conductivity, reduces or destroys the effectiveness of that portion of the heating surface. Further, such accumulations of dust increase the chance that corrosion may escape detection.

5th. Staybolts should not be used. The sole purpose which a staybolt serves in stationary boiler practice is to make it possible to use a cheap form of construction. Staybolts collect scale and mud and increase the difficulty and expense of cleaning. Tubes that may become overheated in case of low water should not be used as stays.



6th. Riveted seams should not be placed in the path of the hottest gases.

7th. It should be possible to make repairs easily. In the Stirling boiler any tube can be removed and replaced without disturbing any other tube. The baffles cannot be easily damaged or displaced in service or by gas explosions, and are so accessible that if a defect be discovered, it can readily be repaired without removing tubes or any part of the setting.

INTERNATIONAL SMELTING AND REFINING COMPANY, TOOELE, UTAH. THIS COMPANY HAS BOUGHT 15,800 HORSE POWER OF STIRLING BOILERS

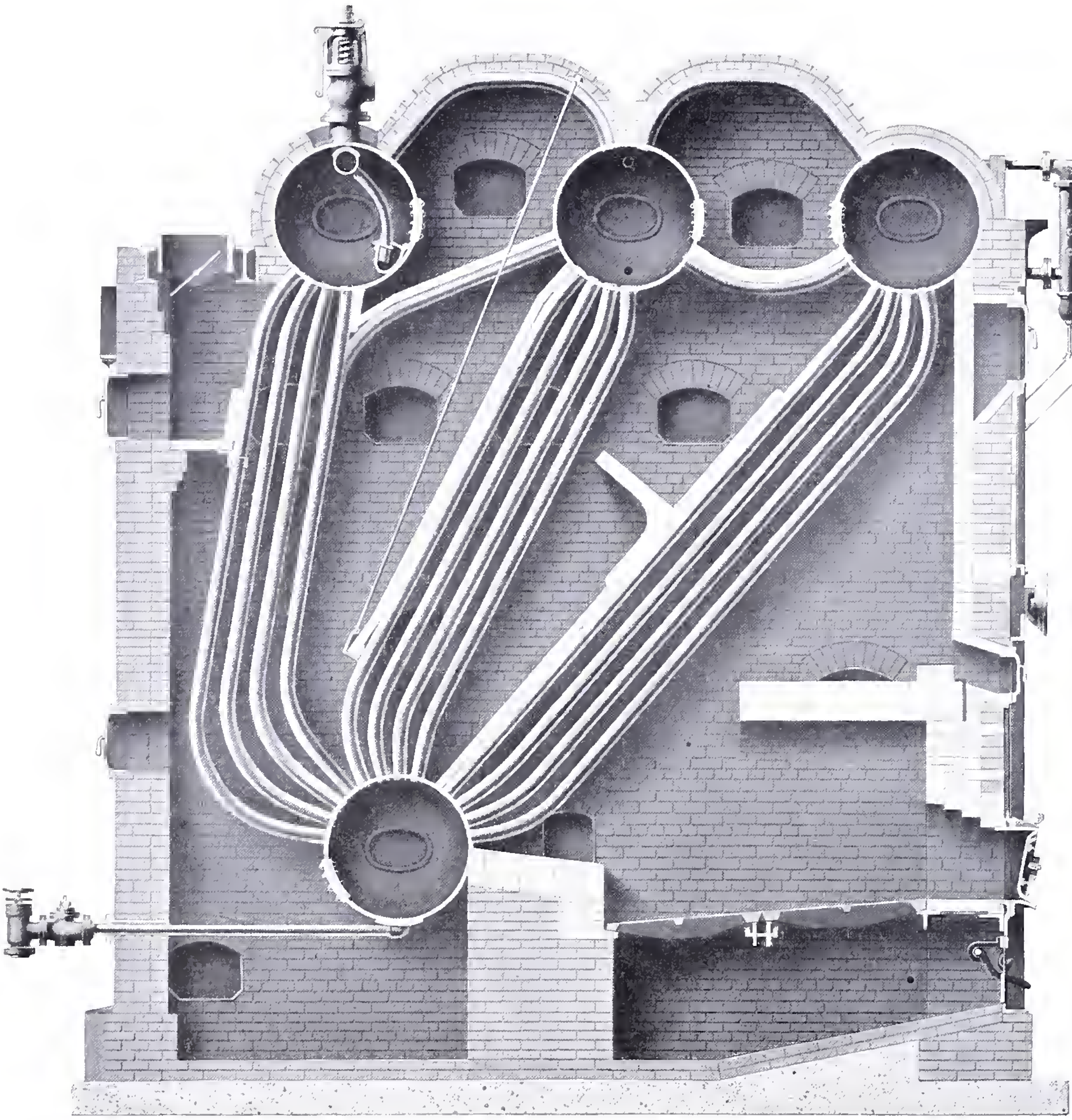
HISTORY OF THE STIRLING WATER-TUBE BOILER

As originally designed by Allan Stirling, the Stirling boiler consisted of a single upper or steam drum and a mud drum. The first boiler was installed at Westville, Nova Scotia. The mud drum was below the grate and connected to the steam drum by a single row of tubes exposed to the products of combustion. The rear and front rows of tubes formed a continuous U which supported a baffle that served as such and as a furnace arch. The remaining and intermediate tubes were drop tubes closed at the bottom. The top drum was made of flat plates supported by staybolts. In service, the boiler gave trouble on account of the burning of the bottoms of the drop tubes and the difficulty of replacing them.

The next step in the development of the boiler was to use two steam drums connected by 2-inch bent tubes to a mud drum. This type, while crudely constructed, demonstrated that the design had enough merit to deserve further improvement, and The Stirling Boiler Company was accordingly formed and in 1890 purchased the interests of The International Boiler Company, Ltd., which controlled the business at that time.

A third steam drum and structural steel supports were added by The Stirling Boiler Company, the plan of the setting was modified, the baffling standardized, the boiler fronts elaborated and improved in construction and the size of the tubes increased to 3¼ inches. This boiler was built with little change in design up to 1898, when numerous details which had proved defective in service were improved. The greatest difficulty experienced in operation was in cleaning the tubes, which was overcome by the development of successful turbine tube cleaners.

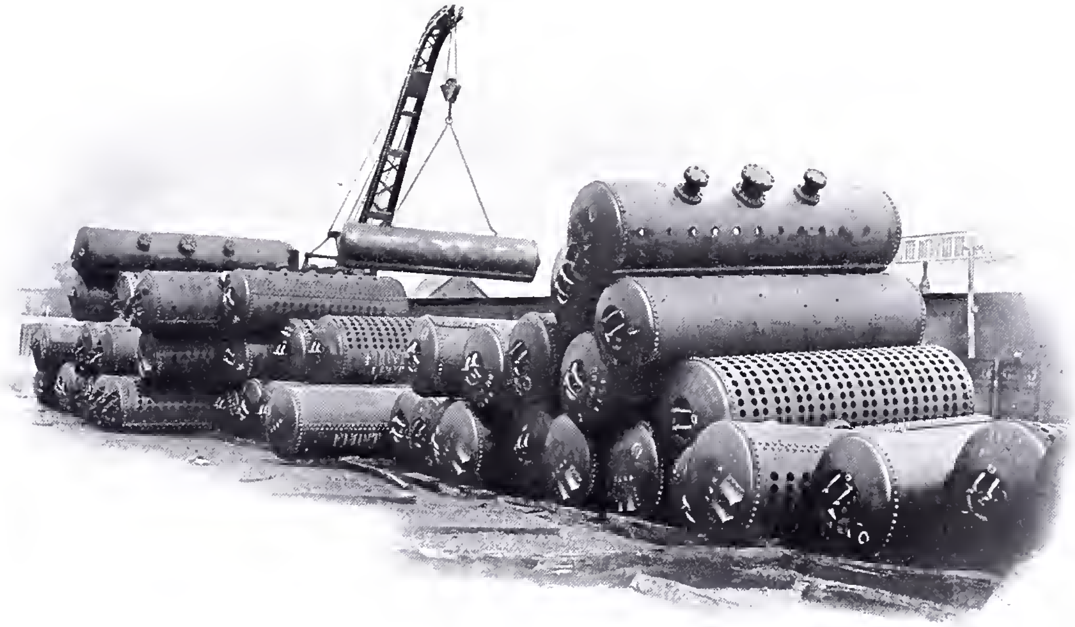
From 1898 on, the Stirling boiler gained favor as its earlier defects were remedied. In 1905, The Stirling Boiler Company acquired other interests and became The Stirling Consolidated Boiler Company. In 1906, the manufacturing plant and business of that company were acquired by The Babcock & Wilcox Company. This company is constantly endeavoring to improve the design, construction and operating qualities of its products. The company believes in being conservative and in refraining from making changes until absolutely satisfied that its developments are sound from engineering, construction and operating viewpoints. This policy has governed the numerous changes made in the Stirling boiler since 1907. In some instances these changes have been introduced to meet special and unusual operating conditions, and others have been the result of improvements in details of design and construction. These changes have been carefully watched and proven under various and difficult conditions of operation. The advantages of many of them in service have been so marked that after years of experience and study they have been incorporated in the boiler described in the following pages.

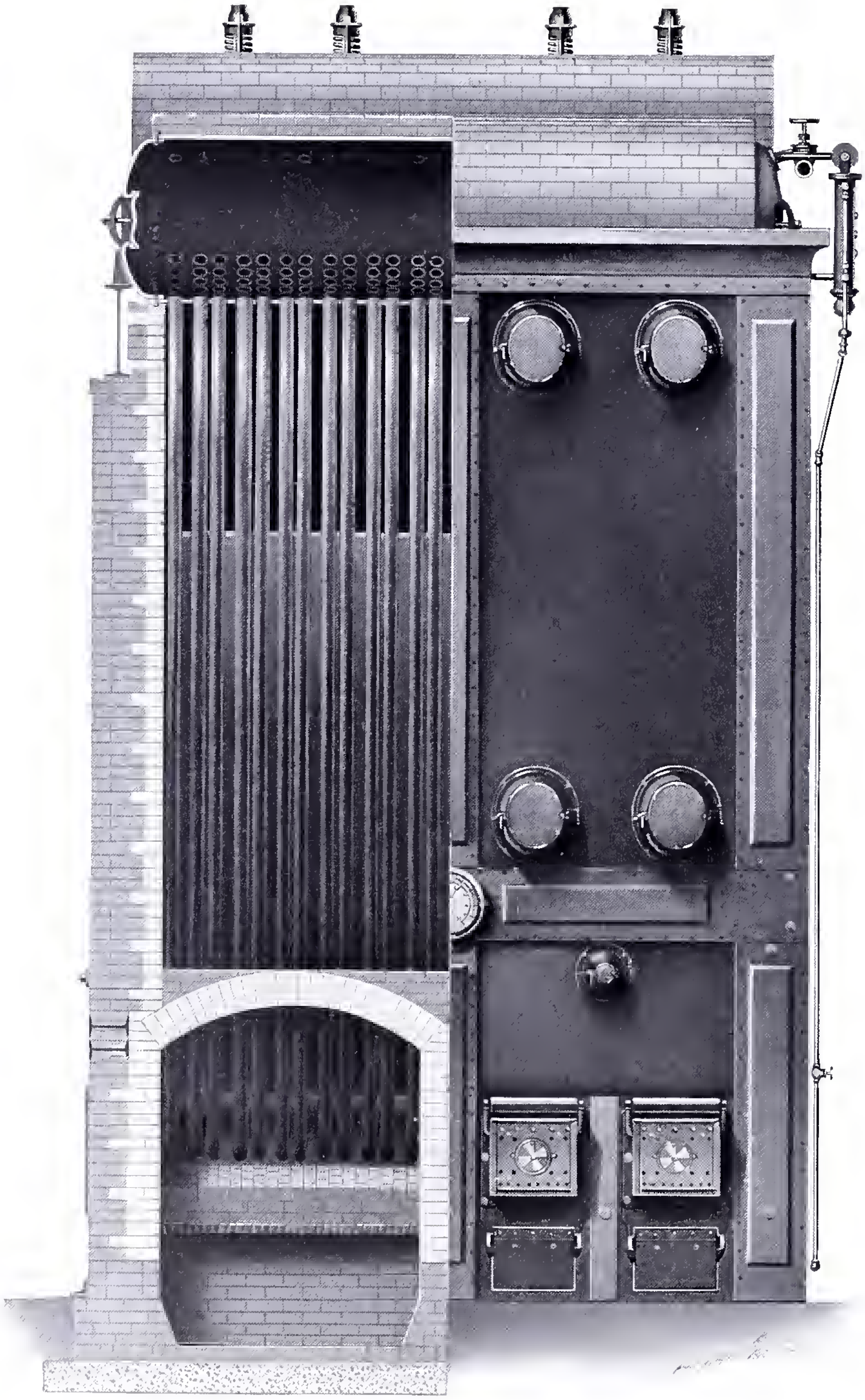


STIRLING BOILER ARRANGED FOR HAND FIRING

For many years, a large proportion of the water-tube boilers built had to be designed to meet specific requirements as to the space they were to occupy. The result of that practice was the evolution of a number of Stirling boilers of about the same heating surface but with quite different over-all dimensions. The different designs were called "classes." Little or no attention was paid to securing any logical method of varying the dimensions of the classes, and there gradually came into existence a great number of classes having little in common as to relative locations of drums, inclinations and lengths of tubes, and ratios of grate to heating surfaces. This was not a desirable condition for either the buyer or builder, and in 1917, when the thorough redesign of the Stirling boiler was undertaken, it was also determined to introduce an entirely new classification in which the variation between the classes and sizes is simple, logical and progressive. This redesign and reclassification was completed in 1921.

While the purchaser of steam boilers is not primarily interested in methods of manufacture, provided they are suitable, it is the purchaser who ultimately receives the benefit of any improvements in such methods. The reclassification of the Stirling boiler led to a reduction in manufacturing costs through a reduction in the inventory of material that must be carried in stock and in the number of standards in use, the greater number of parts applicable to a large proportion of the boilers built, the interchangeability of such parts, the manufacturer's opportunity to build more freely for stock, an increase in the flexibility of the shop procedures, and quicker shipments. While the older classes of the period before 1921 are still built to complete plants in which such classes have been installed, the redesigned and reclassified boiler is offered for all new plants.





PARTIAL FRONT ELEVATION AND SECTIONAL ELEVATION THROUGH FURNACE AND FRONT STEAM DRUM

GENERAL DESCRIPTION

THE Stirling boiler is built in a number of different designs, known as classes, to meet the varying conditions of size, of floor space and of head room. All classes are of the same general design, varying in depth, height and the number and length of the tubes. There are three tranverse steam-and-water drums, set parallel on the same level and connected to a mud drum by water tubes, so curved as to enter the tube sheets radially. The center drum is equidistant from the front and rear drums. The steam space of the center drum is connected to the steam spaces of the front and rear drums by a row of curved steam circulating tubes. The water spaces of the front and center drums are connected by rows of water-circulating tubes, their number depending upon the class of the boiler. The water space of the center drum is connected with the mud drum by one-half the tubes of the front row of the rear bank, which support a baffle protecting the rear steam drum.

The main steam outlet is placed on the top of the rear drum, which also carries the safety valves, of the size and number required by the Boiler Code of the American Society of Mechanical Engineers for the conditions under which the boiler is to operate. A water column is connected to one head of the center drum.

FORGED STEEL DRUM HEAD WITH MANHOLE PLATE IN POSITION

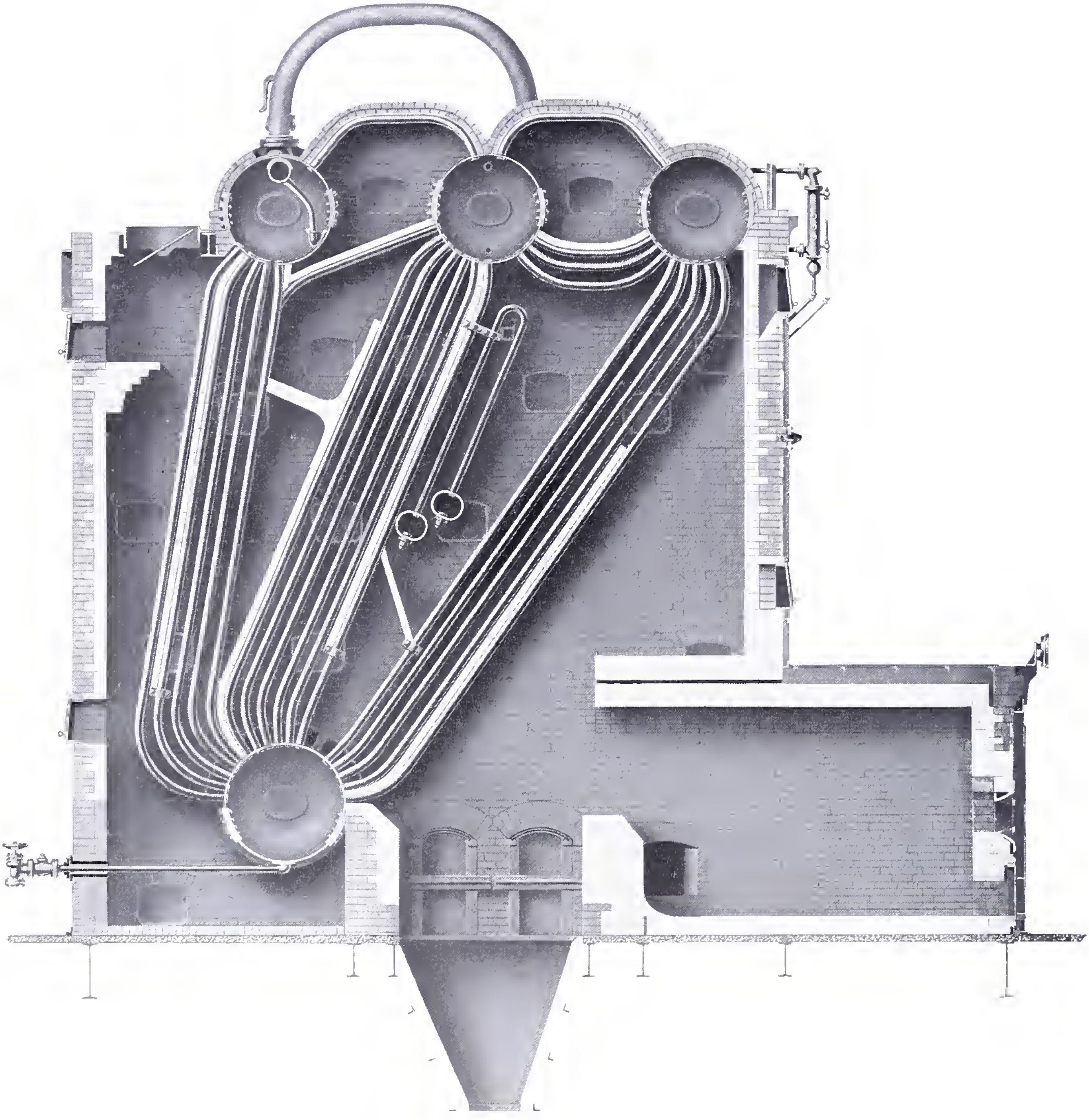
A feed pipe enters the rear steam-and-water drum and discharges into a removable trough, by which the feed water is distributed over a relatively large width of the drum.

A blow-off pipe, or pipes in the case of large boilers, is connected to the bottom of the mud drum and extended through a sleeve in the rear or side wall, just outside which the blow-off valve and cock are located.

The pressure parts of the boiler are supported at both ends of each steam-and-water drum by lugs resting on a rectangular structure of rolled steel sections entirely independent of the brickwork.

Drum Construction—Each drum is made of a tube sheet riveted by properly proportioned butt-and-strap longitudinal seams to a drum sheet. The drum heads are of forged steel, one head in each drum being provided with a manhole fitted with a forged-steel manhole plate and guards.

Tube Spacing—Sufficient space is left between the tubes to permit a free passage of the gases. The tubes are so spaced that any tube may be removed and replaced without disturbing any other tube or the brickwork. After a tube has been removed it is passed out through one of the doors built into the setting for that purpose.



STIRLING BOILER WITH FOUR-PASS BAFFLING, ARRANGED FOR USE WITH BLAST FURNACE GAS

The circumferential arrangement of the tubes on the mud drum gives the largest practicable space for a superheater chamber between the front and middle banks. In classes built before 1921, the tubes were spaced equidistant around the mud drum, with no extra space between the rear tube of the front bank and the front tube of the middle bank. This greatly restricted the lower end of the superheater chamber and made it troublesome to get at the superheater headers. In the classes now offered there is a space left between the front and middle banks equal to the space hitherto occupied by two tubes.

FORGED STEEL DRUM HEAD INTERIOR

BAFFLES—The baffle brick are plain fire-brick tiles, which in the case of the so-called "standard baffle" rest against the rear tubes of the front and middle banks, reaching in the first case from the mud drum nearly to the top of the first bank, and in the second case from the center steam drum nearly to the bottom of the middle bank. When superheaters are not used, a shelf placed near the top of the front baffle deflects the gases into the second bank of tubes. A second shelf is placed in the rear wall near the top of the rear bank of tubes and deflects the gases in their passage upward through this rear bank into the tubes, thus preventing by-passing between the tubes and the rear wall of the boiler setting. Coverings of fire brick resting on the water circulating tubes between the front and middle steam-and-water drums and ontop of the front row of the rear bank of tubes prevent the gases passing above these tubes.

The baffle walls guide the gases up the front bank of tubes, down the middle bank and up the rear bank, bringing them into intimate contact with all of the heating surfaces. The baffle openings between the banks are so designed that there will be a proper distribution of the products of combustion with a minimum amount of throttling action, and can be readily adjusted to suit fuel conditions.

Another form of baffle which is frequently used where fuel and furnace conditions make it advisable is the patented four-pass baffle, one form of which is illustrated on page 20. With this arrangement the front baffle is placed behind the second tube from the furnace, extending from the mud drum nearly to the front steam drum. The second baffle is placed between the front and second tube of the middle bank, extending from the center steam drum nearly to the mud drum. The third baffle is placed behind the rear tube of the middle bank, extending from the mud drum nearly to the center steam drum. Where the gases are taken from the boiler at or near the floor line there is no baffle in the rear bank. Where the gases are taken from the top or rear top of the setting a fourth baffle is placed between the rear two tubes of the rear bank extending from the rear

A PORTION OF THE 35,800 HORSE POWER OF STIRLING BOILERS BOUGHT BY THE BETHLEHEM STEEL COMPANY

steam drum nearly to the mud drum. With this form of baffle the gases make four or, in the case of an overhead stack connection, five passes over the boiler heating surfaces.

The four-pass baffle was originally developed for the purpose of eliminating the boiler furnace arch which was generally installed up to the time of the inception of the baffle. By decreasing the amount of boiler heating surface exposed to the direct radiant heat of the furnace through locating the front baffle behind the second tube of the front bank rather than behind the rear tube of this bank, as high a furnace temperature could be maintained with the four-pass baffle without a boiler arch as with the standard baffle and a boiler furnace arch.

The four-pass baffle has proven very satisfactory when burning fuels the combustion of which results in low or moderate furnace temperature, either with or without a boiler arch. Blast-furnace gas is a fuel of this description and an illustration of a blast-furnace-gas-fired boiler, equipped with a four-pass baffle, is shown on page 20.

Damper Box—A damper box equipped with a swinging damper is placed either on the top of the boiler at the rear of the setting or in the rear wall. In the first instance, it rests on supports carried on the boiler-supporting framework. With such an arrangement it may in turn support an overhead stack and breeching, or it may be connected to an overhead flue. In the second case, the damper is built into the rear wall and is adaptable for any method of rear flue connection.

Expansion—The mud drum is suspended from all of the steam-and-water drums by the water tubes, swinging entirely free of the brick setting. The leakage of air around the ends of this drum is prevented by soft asbestos packing between it and the brickwork. In battery settings, special means of access for inspection of the inside mud drum heads are provided. The method of suspension of the mud drum by curved tubes gives ample provision for expansion and contraction. The design insures thorough equalization and proper distribution of all strains arising while the boiler is in service.

Brickwork*—The setting of the Stirling boiler is simple, being rectangular in outline. No special shapes of bricks not to be found in the open market are required for the setting, and the work can be done by any brick-mason familiar with furnace brickwork and able to read drawings. Where arches are used, the arrangement of the arch skewbacks is such that a complete furnace lining can be installed without in any way disturbing the boiler arch. All masonry repairs to the brickwork can be made without disturbing the pressure parts of the boiler or its connections.

In stoker-fired boilers, except in the case of stokers that support the front wall, this wall is carried on supporting members furnished as part of the standard boiler equipment. Where this is done, a slip joint is used between the front boiler wall and that portion of the wall carried by the stoker. These features not only

*A discussion of Furnace Brickwork is given on page 87.

FRONT OF A STIRLING BOILER

definitely fix the responsibility for carrying the front boiler wall, but give a front wall construction that can be repaired without taking down the entire wall.

Where the size of the boiler renders it advisable, a patented bonding tile construction with properly designed supporting members is used in the front wall. This construction overcomes the tendency of the front wall to spring inward. This construction is used in side walls where necessary.

Where the depth of the furnace required necessitates the moving out of the front wall, the space between this wall and the front steam drum is closed by a suspended fire-brick roof.

Furnace—The form of the Stirling furnace is such as to be readily adaptable to any class of fuel, solid, liquid or gaseous. The large triangular space between the boiler front, the tubes and the bridge wall forms a combustion chamber in which it is possible to install a sufficient amount of grate surface to meet the requirements of the lowest grades of fuel.

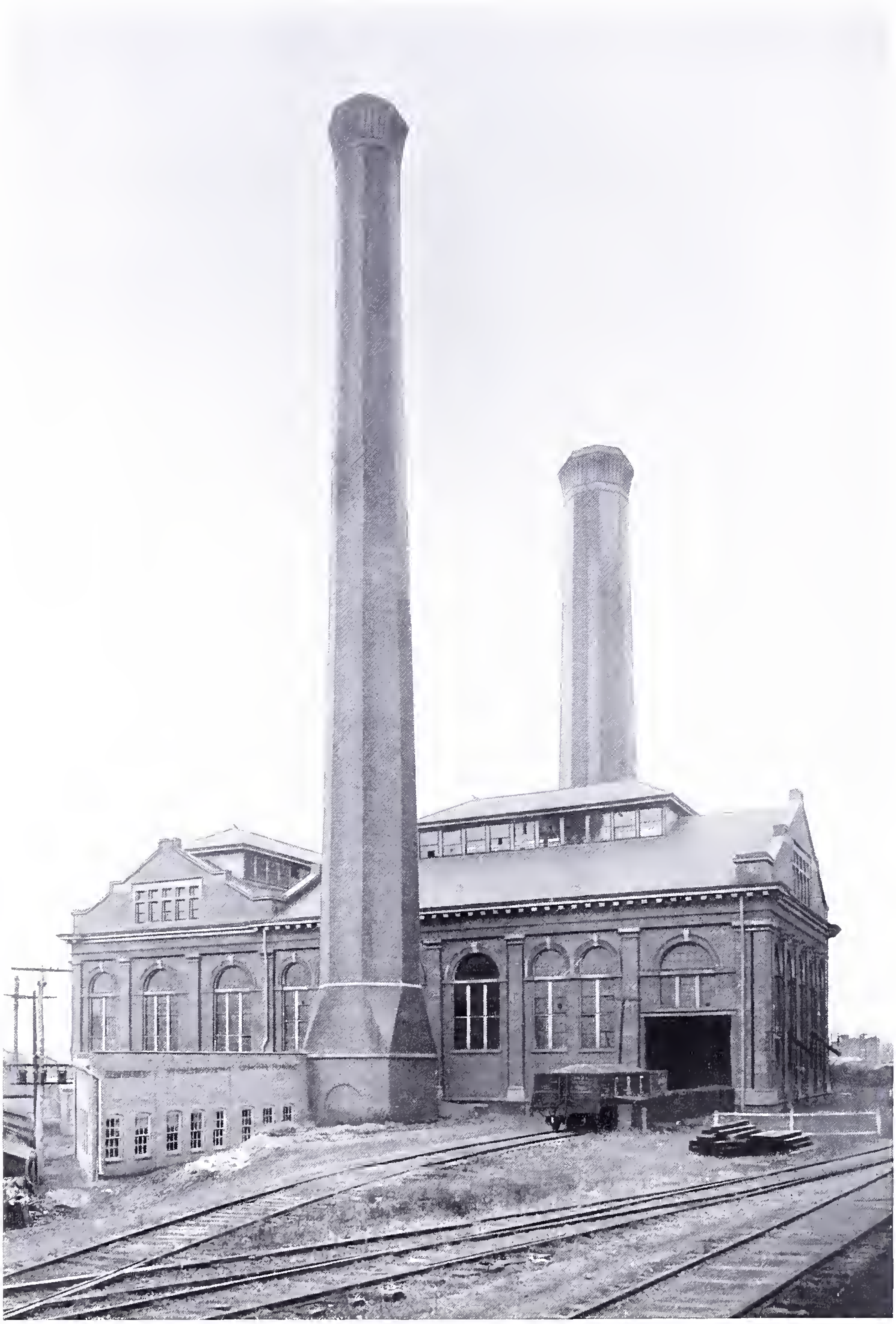
In the case of hand-fired boilers, with certain types of stokers, and when burning certain fuels, where standard baffles are used, a fire-brick arch is placed above the grate in front of the front bank of tubes. This arch, acting as the roof of a reverberatory furnace, by its reflected heat maintains a high furnace temperature and assures the complete combustion of the fuel before the products of such combustion come into contact with the comparatively cool boiler heating surfaces.

The art of burning fuels has progressed rapidly within the last ten years and with many stokers today, both those requiring and those not requiring an ignition arch, where the fuel is suitable, no furnace arch is necessary. Where conditions are proper for the omission of the furnace arch, the boiler should be set at a considerable height above the so-called standard height. Such an increase in height gives an increase in the mass of furnace brickwork radiating heat to the fuel bed, with the resulting maintenance of a high furnace temperature, and also gives the proper space and length of gas travel to assure complete combustion before the boiler heating surfaces are encountered. Further, the increased height of setting minimizes the possibility of a laneing action of the products of combustion through the front bank of tubes.*

Front—The front is of ornamental design, substantially made of cast iron and steel, and is built up in sections and bolted together. The joints are so placed as to permit the use of any stoker or of oil, gas, or pulverized fuel burners. The joints provide for all expansion and thus prevent warping and cracking.

Access and Cleaning Doors—Doors for cleaning the heating surfaces and for access to the interior of the setting are provided in the front, side and rear walls in sufficient number to allow all parts to be cleaned thoroughly by

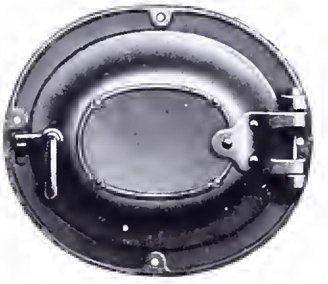
*No discussion of the principles upon which successful furnace design must be based will be given in this book, as they are fully explained in a treatise on "Principles of Combustion in the Steam Boiler Furnace" by Arthur D. Pratt, published by The Babcock & Wilcox Company.



INDIANAPOLIS LIGHT AND HEAT COMPANY, INDIANAPOLIS, IND., WHICH HAS BOUGHT 18,400 HORSE POWER OF STIRLING BOILERS

means of a steam lance and to make the exterior of the heating surfaces easily accessible for inspection. All cleaning doors are set tight against asbestos packing, hammered into a groove in the face of the door frame, in this manner preventing the leakage of air into the setting.

A large circular door in the setting gives access to the manhole end of the mud drum. This door is also asbestos-packed to prevent air leakage.

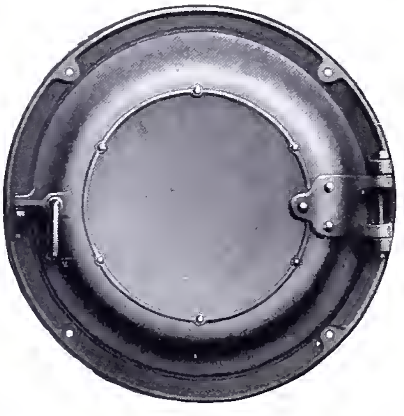


ACCESS AND CLEANING DOOR

INTERIOR CLEANING—Removing the manhole plates from the four drums gives easy access to the interior of all heating surfaces for examination, cleaning and repairs.

Any scale which may form on the inner surfaces of the tubes can be removed by a turbine cleaner of any of the many designs on the market. The hose to which the cleaner is attached is passed into the drum, the operator running the cleaner through the tubes by means of the hose.

FITTINGS—The boiler accessories consist of the following:



MUD DRUM ACCESS DOOR

Feed water connections and valves attached to the rear steam-and-water drum.

Blow-off connections, valves and cocks connected to the mud drum.

Safety valves placed on the rear steam-and-water drum.

A water column fitted with gauge cocks connected to the center steam-and-water drum and placed in a position visible from any point forward of the boiler front.

A steam gauge attached to the boiler front.

All of these fittings are substantially made and are of designs which, by their successful service for many years, have become standard with The Babcock & Wilcox Company.

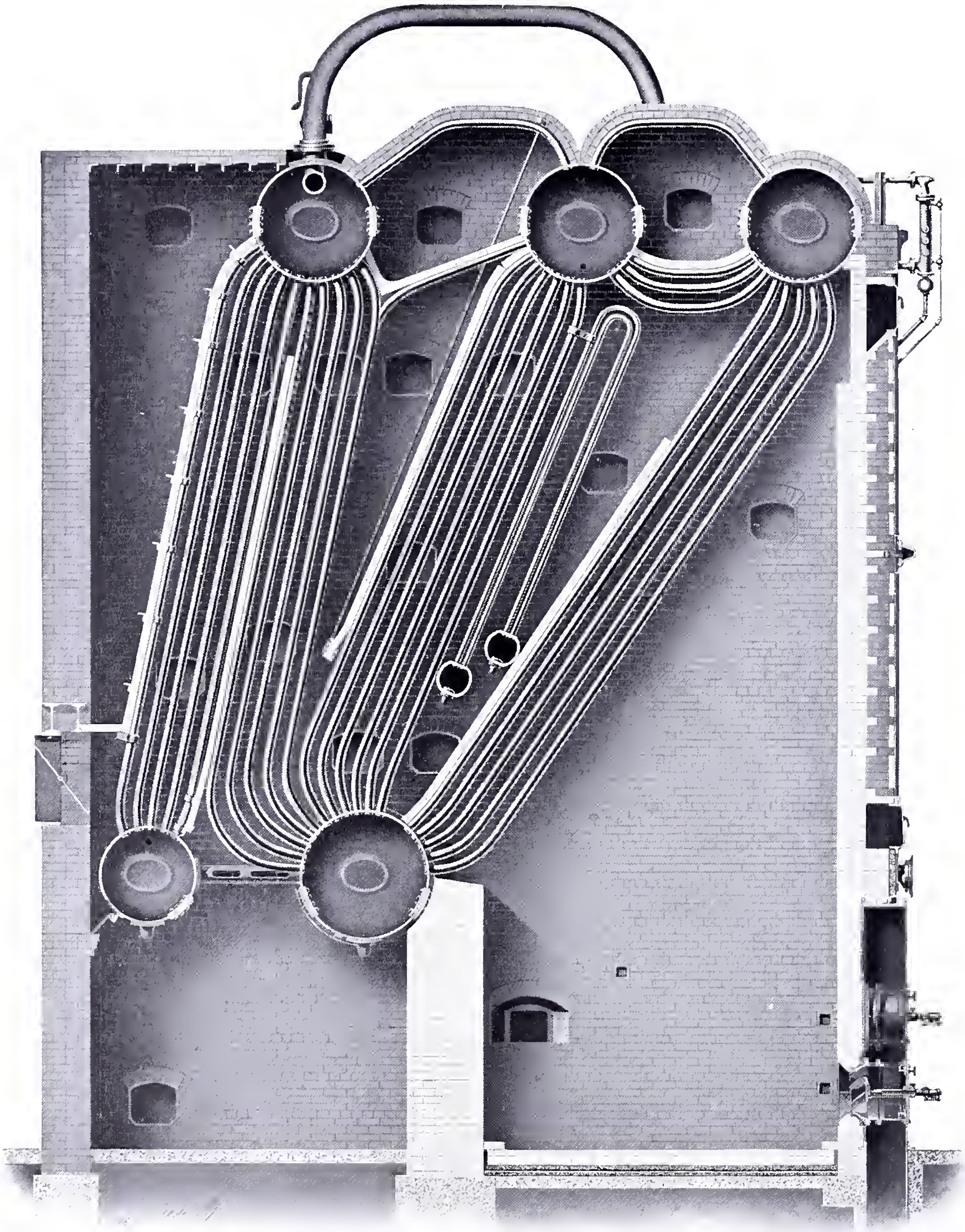
OPERATION—The path of the gases from the furnace has already been indicated. The water, which is fed into the rear steam-and-water drum, passes downward through the rear bank of tubes to the mud drum, thence upward through the front bank of tubes to the front steam-and-water drum. The steam formed during the passage upward through the front bank of tubes becomes separated from the water in the front drum and passes through the steam circulating tubes into the middle drum and then, with the steam generated in the middle bank of tubes, into the rear drum, from which it passes through the dry pipe into the steam main. The water from the front drum passes through the water circulating tubes into the middle drum and thence downward through the middle bank of tubes to the mud drum, from which it again passes up the front bank to retrace its course.

GUANICA CENTRAL, GUANICA, PORTO RICO, WHICH HAS BOUGHT 8100 HORSE POWER OF STIRLING BOILERS

The great water storage capacity of the four drums and the tubes, together with the large steam-disengaging surface of the three steam-and-water drums, and the withdrawal of the steam from the rear drum, insure the production of dry steam under varying loads and irregular firing conditions.

Bad Feed Water—In its passage downward through the rear bank of tubes, the feed water is heated to such an extent that much of the scale-forming matter is precipitated and gathers in this bank and in the mud drum. Here it is protected from high temperatures and can be washed and blown down as frequently as the case demands. As the circulation is comparatively slow in the rear bank of tubes, a large percentage of matter held in suspension in the feed water is deposited in the mud drum before reaching that portion of the heating surface subjected to intense heat.

The importance of good feed water is so great that a discussion of the subject is given on pages 69 to 85.



STIRLING BOILER WITH INTEGRAL ECONOMIZER AND BABCOCK & WILCOX MECHANICAL OIL BURNER

THE STIRLING INTEGRAL ECONOMIZER UNIT

WITH increasing fuel costs, engineers today are making every endeavor toward the utilization of as large a proportion of the heat of combustion of the fuel as possible. A method of increasing boiler-room efficiency in common use is through the installation of economizers, through which the feed water is passed and over which the products of combustion are taken after they leave the boiler. The tendency toward higher boiler capacities, with the consequent higher temperatures of gases leaving the boiler, has, next to increasing fuel costs, been the most important factor in the bringing of economizers into more general use.

Engineers are not in entire agreement regarding economizer practice. While many favor economizer installations, others believe that it is better practice to install, instead of a given amount of economizer surface, the same amount of surface as boiler-heating surface, maintaining the same width of boiler furnace as if an economizer were to be used, and increasing the amount of boiler surface per foot of furnace width, thus obtaining an increase in efficiency of heat absorption for a given combustion rate, or for a given rate of steam output from the boiler.

Those engineers favoring economizer installation base their judgment on the better temperature gradient that exists with economizers. The temperature of the heating surface of a boiler is ordinarily assumed to be that due to the pressure within the boiler, while that of the economizer surface will, in the case of a strictly counterflow design, be the mean of the entering and exit feed-water temperatures. Under such conditions, due to the greater temperature difference between gases and absorbing surfaces, the total absorption by a given amount of economizer surface would be greater than the total absorption by an equal amount of surface added as boiler heating surface. While the temperature difference would have but a slight effect on the rate of heat transfer itself, it might have an appreciable effect on the total absorption.

Those engineers who favor an increase in boiler heating surface per foot of furnace width by an amount equal to what would be installed as economizer surface, while recognizing the theoretical and actual advantage of the economizer surface over the same amount as added boiler surface, claim that such advantage is not sufficient to offset other factors entering into the problem. They claim for the increase in boiler surface, lower first cost, lower maintenance cost, lower draft loss, reduced possibility of air leakage and, in general, greater simplicity of installation and operation of the unit as a whole.

Both types of installation have their field and obviously the choice between them must be considered for every individual installation as a separate engineering problem. The cost of fuel is beyond question the primary factor involved in

GARFIELD SMELTING COMPANY, GARFIELD, UTAH, OPERATING 7000 HORSE POWER OF STIRLING BOILERS

determining the extent to which is justified the additional expense of a boiler and economizer installation over that of the same amount of surface in a boiler alone. The saving due to one or two per cent additive efficiency in the case of the economizer installation, when capitalized, may or may not warrant the increased investment as the fuel cost increases or decreases.

While the use of steel tube economizers in this country is not new, this class of apparatus has until recently, because of lesser danger from rapid corrosion, been constructed of cast iron. For the past few years the tendency toward higher boiler pressures has induced engineers to turn to a construction other than cast iron, and naturally steel-tube economizers were the first to be considered.

With the present-day boiler pressures, the increased safety of wrought-steel construction over cast iron more than offsets the greater tendency toward more rapid corrosion in the case of the former. With this recognized, the problem becomes the use of the safer construction and obviating or minimizing the possibility of corrosion either external or internal. Further, it is probable that the use of cast-iron economizers for the higher pressures will be limited by law, as in the case of present-day boiler construction.

External corrosion, which ordinarily occurs at the cold end of an economizer, is the result of condensation of the moisture content of the products of combustion on the cooler surfaces of the economizer. Experience has shown that the danger from external corrosion can be made negligible by the use of feed temperatures entering the economizer of from 120 to 140 degrees Fahrenheit.

With such temperatures there is but little danger of external corrosion except in the case of intermittent operation, as it is during the cutting in and out of a boiler and economizer unit that condensation will take place. In the average plant where steel-tube economizers would be used, the operation is as nearly as possible continuous, and even when the operation is more or less intermittent the danger from external corrosion may, with proper care, be reduced to a minimum.

Interior corrosion is ordinarily the result of air or oxygen contained in solution in the feed water. Water, reasonably pure and after natural exposure to the atmosphere, contains when fully saturated at ordinary temperatures, approximately 16 parts by volume per 1000 parts of water, the air being under standard pressure and temperature conditions. Water in such condition is actively corrosive to steel surfaces even at temperatures as low as 100 degrees Fahrenheit, and its use at temperatures between this point and the boiling point leads to rapid and severe pitting. The quantity of air that may be held in solution by water decreases as the water approaches its boiling point, under a given pressure.

It may be stated as a definite fact that with the elimination of air in feed water to a sufficient degree, the danger of internal corrosion of steel-tube economizers is negligible.

There is some disagreement among engineers as to the proper methods to be followed for the removal of air from feed water that is to be passed through

4800 HORSE-POWER INSTALLATION OF STIRLING BOILERS FOR THE MARQUETTE CEMENT MANUFACTURING COMPANY, LA SALLE, ILL.

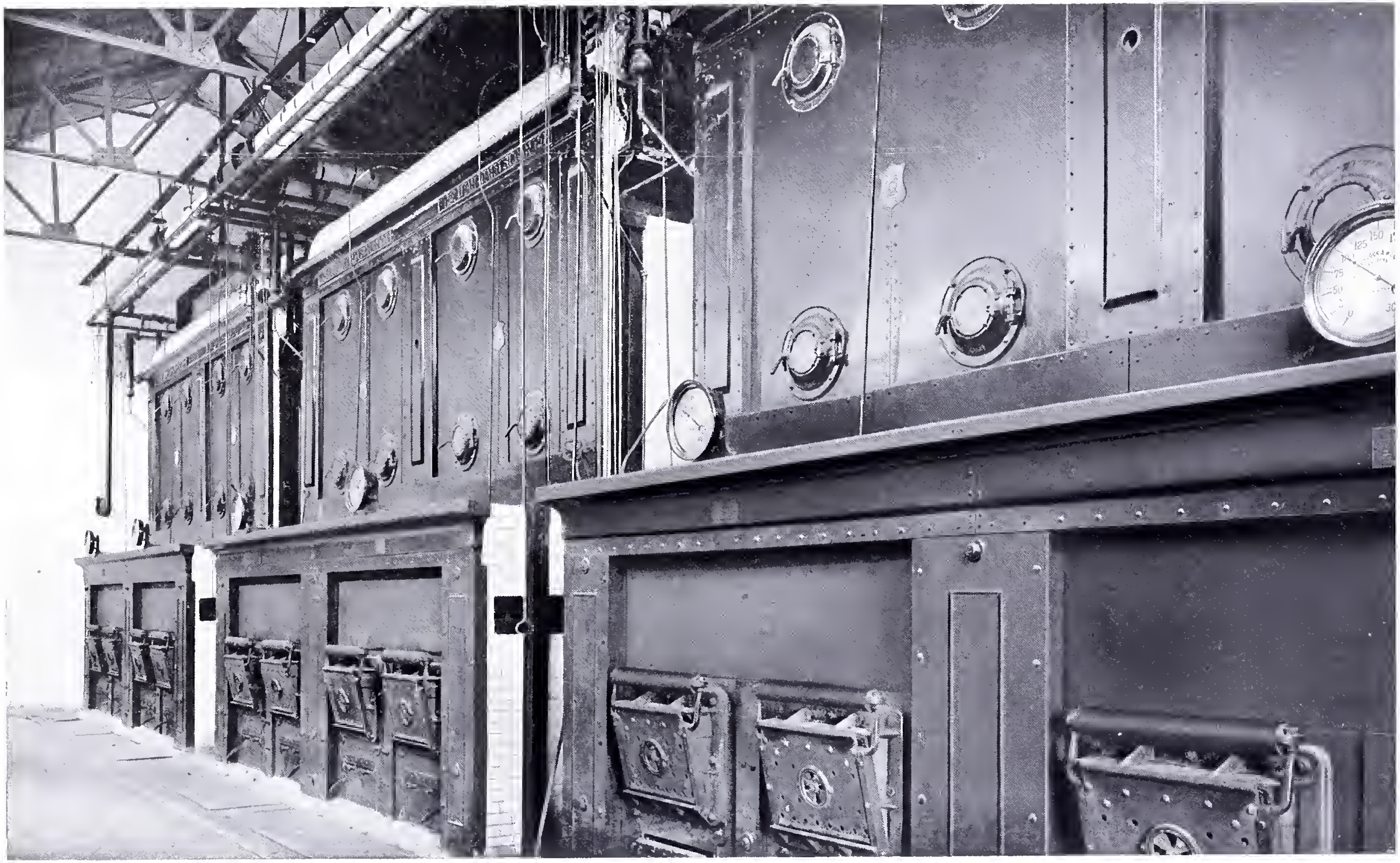
steel-tube economizers. Such air may be removed to a sufficient degree by heating the feed water before entering the economizer to a temperature at which air elimination is assured. Such a method, while positive, results in a temperature of feed water entering the economizer higher than is desirable from the standpoint of maximum economizer efficiency.

A second method of air removal, which, from the consideration of economizer return, because of lower feed temperature entering the economizer, is thermally more efficient than the primary heating of the feed, is the elimination of air to the desired degree at a temperature which, while low, corresponds to that necessary from the standpoint of exterior corrosion. Such a system, which is available commercially, is based on the principle of reducing the boiling point of the feed water, or the elimination of dissolved air through boiling of the water, at a temperature favorable to economizer performance, *i. e.,* the boiling of the feed under a vacuum.

A number of installations of steel-tube economizers have been made where low-feed temperatures are used and air elimination is not attempted. In such cases the interior of the economizer surfaces have been given some sort of a non-corrosive protection. This method has been tried with a greater or lesser degree of success, but in this respect the art cannot be said to have become stable. To repeat, however, it may be safely stated that there are methods of air removal available which render the danger of interior corrosion in steel-tube economizers practically negligible and which still enable the temperature of the feed water entering the economizer to be such as will lead to the maximum economizer efficiency in heat absorption.

The Stirling integral economizer is one of the designs of steel-tube economizers developed by The Babcock & Wilcox Company to meet the requirements of present-day boiler pressures. The construction of this type of economizer, which is illustrated on page 30, is simple and leads to a particularly compact arrangement of boiler and economizer surface. A second mud drum, of somewhat smaller diameter than the standard mud drum, is added to the standard Stirling boiler, this drum being connected by a bank of curved tubes to the rear steam-and-water drum of the boiler. The feed water is introduced into this rear mud drum, the products of combustion passing downward over the tubes. While not as strictly counterflow in principle as other types of wrought-steel economizers offered by The Babcock & Wilcox Company, tests in which the rise in water temperature through the economizer element has been determined have shown that but little, if any, reverse circulation in this element takes place, and practically the full advantage of counterflow of gas and water is present in this design.

The amount of economizer surface, in terms of boiler heating surface, that may be installed with this design of economizer is limited to approximately 30 per cent and is perhaps less than is general in economizer practice. It is to be



ONE OF NINE 1505 HORSE-POWER INSTALLATIONS OF STIRLING BOILERS FOR THE UTAH IDAHO SUGAR COMPANY, WHICH HAS BOUGHT A TOTAL OF 21,800 HORSE POWER OF THESE BOILERS

remembered, on the other hand, that the first 50 per cent of surface of any economizer that may be installed absorbs some 70 per cent of the total heat absorbed by the average economizer. Further, if conditions warrant, an economizer of this design may be used as the high-pressure stage of a two-stage economizer, a low-pressure stage through which the feed is first passed being placed behind the integral economizer element. Such an arrangement has been installed and has been satisfactory in operation in numerous plants.

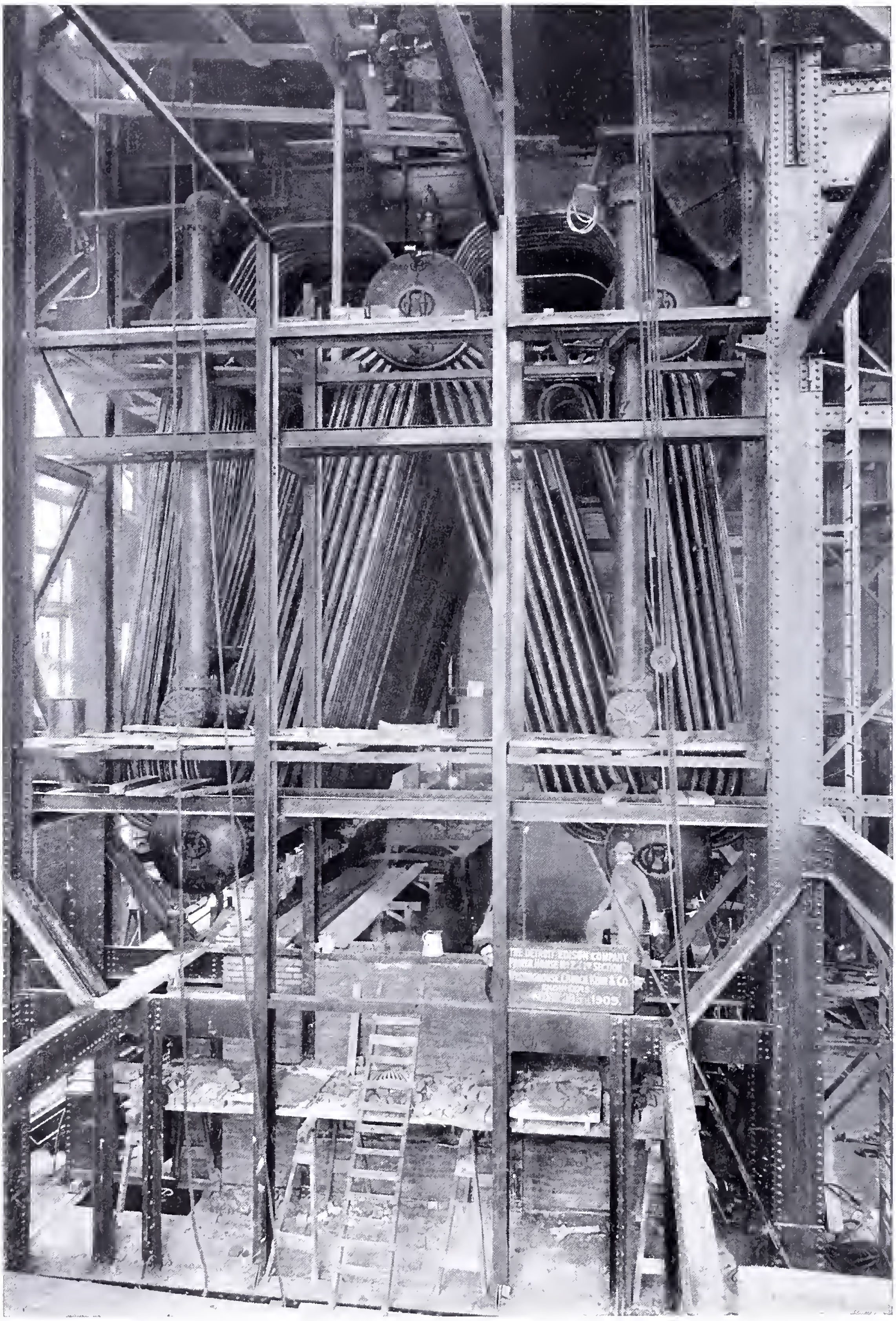
As stated, the integral type Stirling economizer offers a particularly compact arrangement of boiler and economizer surface. This compactness leads not only to a minimum setting cost but to what is, in economizer work, one of the most important factors to be considered, the reduction of the probability of air infiltration to a degree affecting neither economizer nor fan performance.

The draft loss, which, due to the negative stack effect of the down passage of gas, might be greater than that through an equal amount of surface in an upward or horizontal gas flow economizer, is still low, and appreciably less than any leeway that an induced or forced-draft fan would be specified to give.

The heating surface of the Stirling integral type of economizer is arranged in such manner as to enable it to be cleaned by the same methods as are employed in the keeping of the boiler surfaces free from soot and dust. This fact, together with the compactness of setting already discussed, results in a minimum air infiltration.

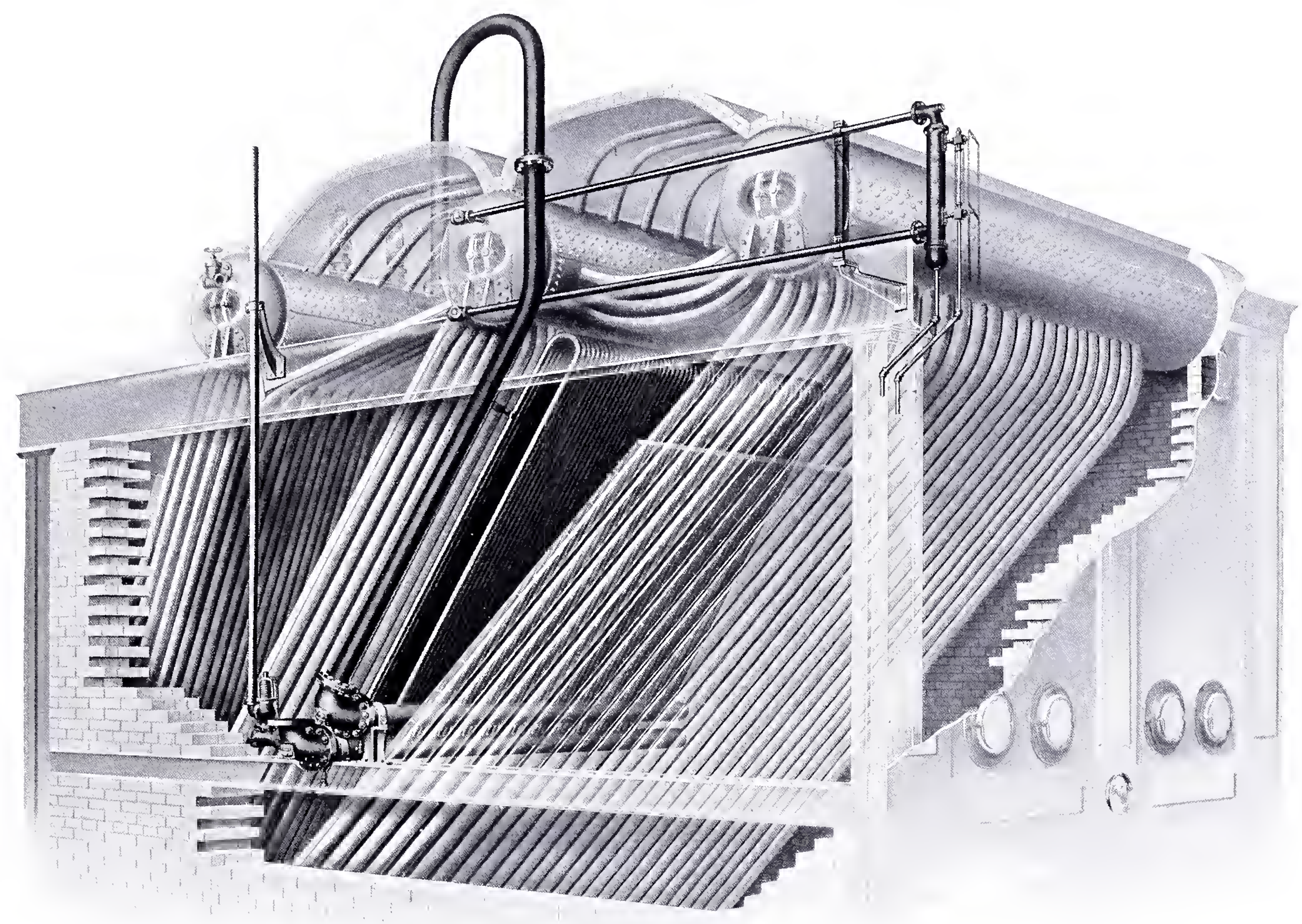
There is one factor to be considered in the installation of economizers which, in common with the installation of all the apparatus included in a complete steam generating unit ready to function, has not been fully appreciated. This is the factor of single and undivided responsibility for the installation and operation of the unit as a whole. The ideal installation of a complete steam generating unit is, from the standpoint of the purchaser, a combination of boiler, superheater, stoker and economizer, designed, built, and installed by a single manufacturer. Under such conditions, the failure of any single part of the combined apparatus cannot be blamed on the performance of any other part or parts supplied by another or other manufacturers. Further, the complete installation of the unit as a whole by one manufacturer tends toward minimum cost to the purchaser in that there is no question as to where the work of one manufacturer stops and that of another begins, with the consequent elimination of the possibility of any "extras" in the cost to cover the contingencies which might arise from such a question of responsibility.

From the standpoint of the manufacturer, as well as from that of the purchaser, the undivided responsibility for the installation and operation of the complete unit is desirable. Under conditions of single responsibility, there can be no chance that the failure of a portion of the apparatus of manufacture other than his own can be blamed on such portion as is of his own design and manufacture which is properly functioning. The purchaser of a complete steam



2365 HORSE-POWER STIRLING BOILER IN COURSE OF ERECTION AT THE DELRAY, MICH., STATION OF THE EDISON ELECTRIC ILLUMINATING CO., OF DETROIT. THIS COMPANY HAS INSTALLED 71,500 HORSE POWER OF STIRLING BOILERS

generating unit, the individual elements of which are designed, built, installed and put into operation by a single reliable and responsible manufacturer, can rest assured that such manufacturer has so designed and built the unit as a whole, that there will be a co-ordination in the functioning of the separate elements of the unit which will result in satisfactory and continuous service.



PHANTOM VIEW OF BABCOCK & WILCOX SUPERHEATER AS ORDINARILY INSTALLED IN STIRLING BOILERS

BABCOCK & WILCOX SUPERHEATERS AS APPLIED TO STIRLING BOILERS

STEAM superheaters were first introduced commercially in the United States by The Babcock & Wilcox Company in 1898, and by far the greater number of superheaters used with boilers of its manufacture have been supplied by this Company.

LOCATION—The Babcock & Wilcox superheater, as applied to Stirling boilers, is located in the triangular space between the front and middle bank of boiler tubes, the superheater tubes being parallel to the boiler tubes of the second bank. This location with relation to the boiler pressure parts, which is indicated by the illustration on the opposite page, is covered by patent.

CONSTRUCTION—The superheater is made up of two superheater manifolds or headers connected by inverted U-tubes.

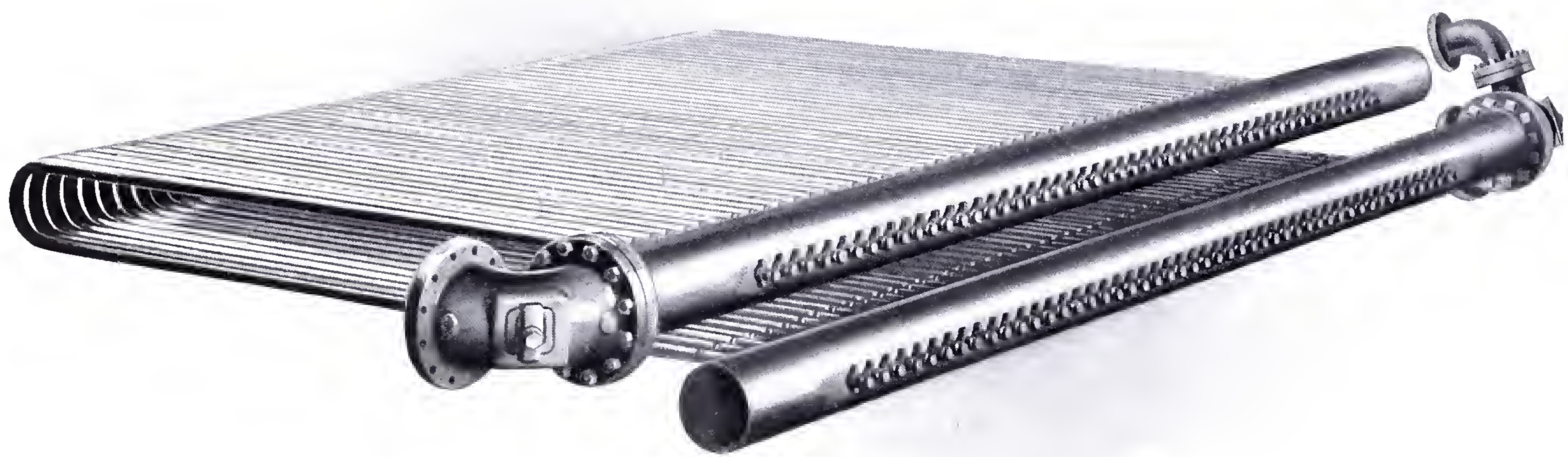
The superheater headers are of extra heavy wrought-steel pipe of sufficient diameter to give the desired steam velocities through this portion of the apparatus, and are flattened slightly top and bottom for that portion of their length into which the superheater tubes are to be expanded and in which the handholes are included.

The tubes are of 2-inch cold-drawn seamless steel, bent to a U shape, and are expanded at the ends into bored seats in the upper flattened surface of the superheater headers. By a variation in the length and spacing of the tubes, the requisite amount of surface is provided to give the desired degree of superheat.

Opposite each tube end in the lower flattened surface of the superheater headers there is provided an individual handhole which gives access to the tube for expanding and inspection. These handholes are machine-faced back from the edge a sufficient distance to make a seat and are closed by circular, inside-fitting, forged-steel handhole plates shouldered to center in the opening, the flanged seats being milled to a true plane. A ¾-inch bolt, forged integral with the handhole plate, extends through the opening, and a wrought-steel crosspiece, extending across the opening on the outside, holds the plate in place. The bolt extending through the crosspiece receives a cap nut which protects the threads from possible oxidization. The joints between header and handhole plates are made with a thin gasket.

The tubes are ordinarily equipped with ferrules or cores, as conditions warrant, to give a proper ratio of tube cross-sectional area to header area. By the use of this construction, it is assured that all tubes carry their proper proportion of the total amount of steam passing through the superheater, and the danger of warping or burning of any tubes due to being by-passed is obviated.

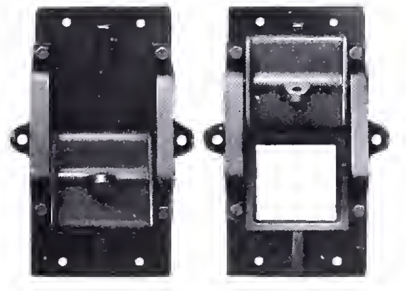
One end of each superheater header is welded closed. To the other end there is attached a wrought-steel flange.



BABCOCK & WILCOX SUPERHEATER AS ORDINARILY INSTALLED IN STIRLING BOILERS

Steam is taken through the boiler dry pipe from the saturated steam outlet on the rear drum by means of tubes of suitable diameter expanded at the ends into wrought-steel flanges. A special cast-steel flanged inlet elbow connects the intake pipe to the intake superheater header. The steam then passes through the tubes to the outlet header, to the flanged end of which is attached a special cast-steel superheated steam outlet fitting. This fitting has a standard extra heavy flanged outlet to which the superheated steam connection from the boiler is made and a similar flange to which the steel-bodied, outside spring, superheater safety valve, which is part of the standard superheater equipment, is attached.

The inlet and outlet superheater fittings are provided with square handhole fittings which give access to the inlet and outlet connections and to the superheater headers. These handholes are closed by square, inside-fitting, forged-steel handhole plates, held in position by forged-steel guards and nuts, the joints between plates and seats being made with thin gaskets.



SUPERHEATER DUSTING DOORS

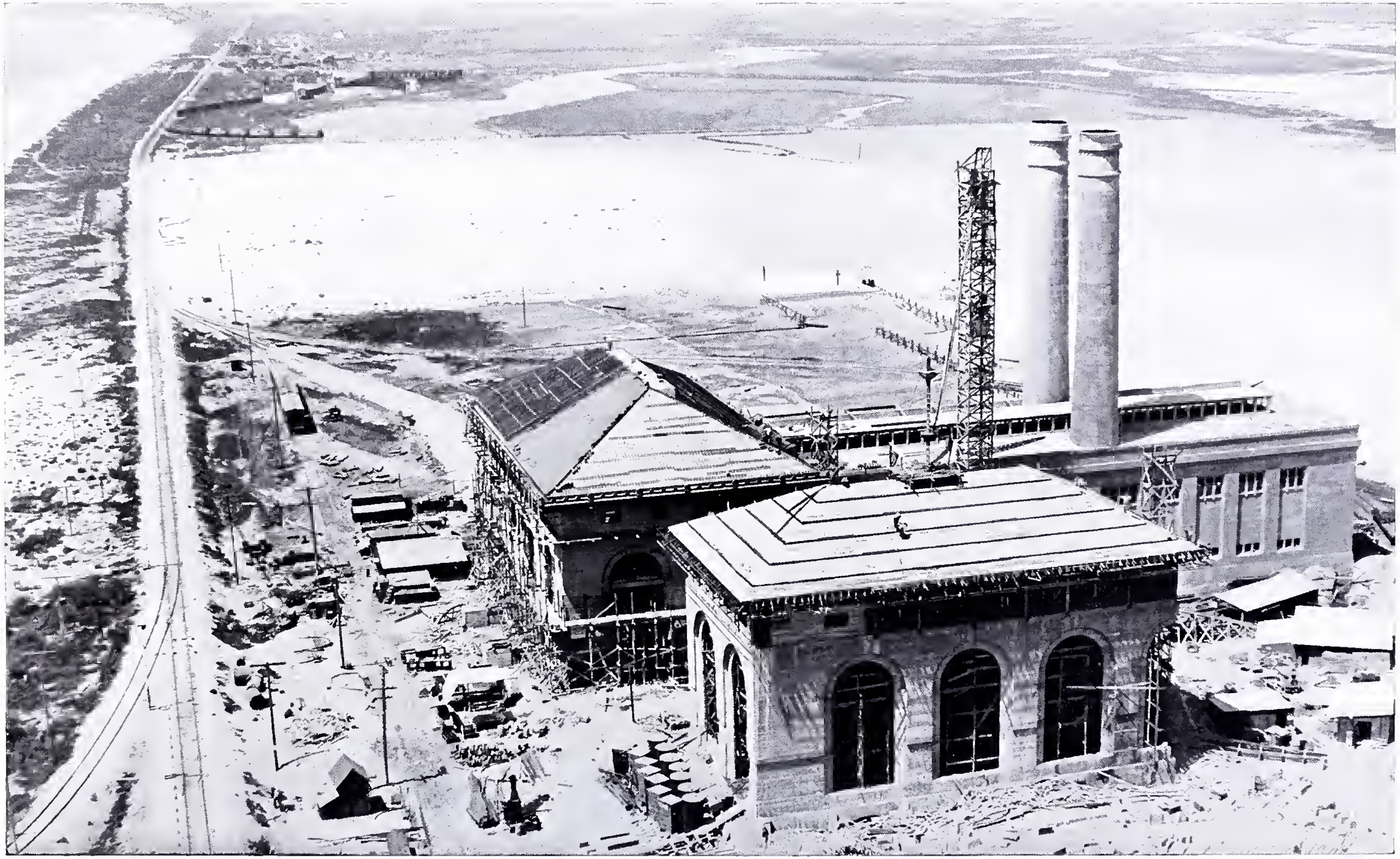
Drain pipes and valves are provided for draining any water of condensation that may collect in the superheater headers when no steam is passing through. Babcock & Wilcox superheaters can be completely drained.

Supports—The superheater headers are carried at both ends on saddles attached to members which are framed into the boiler structural supports. The overturning moment of the superheater is taken care of by straps attached to the saddles, and which pass over the boxes at the end. These, together with tube clamps toward the top of the rear leg of the superheater tubes, attached to the front tube of the middle bank of boiler tubes, hold the superheater in position, and are so arranged as to allow for longitudinal expansion of the headers.

Accessibility—Large doors in the side walls of the boiler setting give access to the space beneath the superheater headers, by the use of which inspection, cleaning and repairs may be readily accomplished. Other doors give access to the space in front of and between the tubes and allow all parts of the superheater to be kept thoroughly clean.

The superheater location and construction as described are such as to meet every requirement of the properly designed steam superheater. These requirements may be briefly summarized as follows:

Since the surface of the superheater is at a higher temperature than the boiler heating surface, a corresponding increasing care must be taken in the design of the superheater to obviate temperature strains. This is accomplished in the Babcock & Wilcox superheater by the U form of the tubes and the method of supporting the superheater as a whole.



EXTERIOR OF THE LONG BEACH, CAL., PLANT OF THE SOUTHERN CALIFORNIA EDISON COMPANY

The surface of an integral type superheater should be so located as to be swept by all of the products of combustion; that is, the same gases that pass over the boiler surfaces should also pass over the superheater. An arrangement by which a portion of the gases are by-passed from the furnace to the superheater direct, without passing over any of the boiler surface, will ordinarily lead to a decreased combined boiler and superheater efficiency, even though the gases after leaving the superheater pass over the boiler surface beyond the superheater. The location between the first and second banks of tubes, in the direct path of all the gases which have passed over the front bank, gives assurance that the Babcock & Wilcox superheater as applied to Stirling boilers fully meets this requirement.

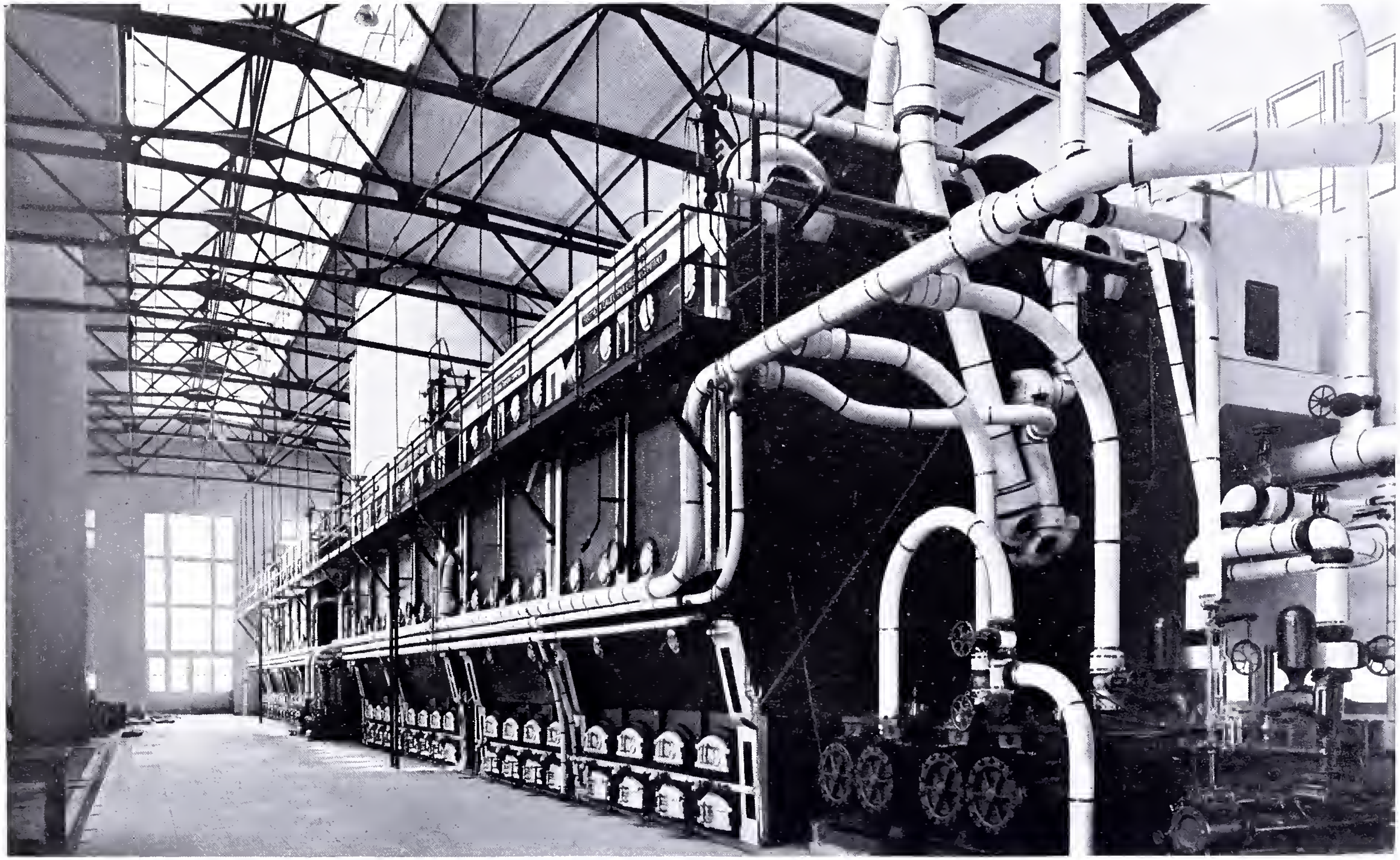
While in the direct path of all of the products of combustion, the location must also be such as to allow full and easy access to all parts for inspection and cleaning. Suitable handholes should be supplied for inspection of superheater headers and tubes. Expanded tube joints, with tube ends flared, give the best construction, and no flanged joints should be exposed to the hot gases. The general description indicates how fully these essential features have been considered in the design of Babcock & Wilcox superheaters.

The surface of a superheater should be arranged to give a maximum heat absorption and at the same time the arrangement must be such as to lead to a minimum draft resistance to the gases in passing over the superheater. This twofold requirement is accomplished in the Babcock & Wilcox superheater as applied to Stirling boilers by the superheater location in combination with the proper spacing of superheater tubes.

The superheating surface should also be arranged in such manner as to offer a minimum opportunity for the lodging of soot and dust. This is accomplished in the Babcock & Wilcox superheater through the use of smooth surfaces and the proper arrangement and spacing of the tubes with reference to the direction of gas flow. Such small amounts of soot and dust as do adhere to the smooth surfaces may be readily removed by the methods used in cleaning boiler surfaces.

The superheating surface must be arranged in such manner that the steam passes evenly and in equal amounts through all of the superheater elements. This requirement is assured of fulfillment in the Babcock & Wilcox superheater by giving the proper ratio between header area and total cross-sectional area of superheater tubes.

All superheaters should be equipped with safety valves set to blow at a pressure below that at which the boiler safety valves are set. With such equipment, a flow of steam through the superheater is assured should the load be suddenly thrown off the boiler, and the superheater, through this flow, is protected against the possible burning which might occur were the saturated steam valves to blow first. Safety valves are part of the standard equipment of all Babcock & Wilcox superheaters.



6220 HORSE-POWER INSTALLATION OF STIRLING BOILERS FOR THE SOUTHERN CALIFORNIA EDISON CO., LONG BEACH, CAL
THIS COMPANY HAS BOUGHT 34,900 HORSE POWER OF STIRLING BOILERS

Superheaters should be equipped with suitable drains. Where arrangement for thorough draining of superheaters is not provided, there is danger that in intermittent service, slugs of water will be carried over to the prime movers with results that might prove disastrous. All Babcock & Wilcox superheaters are so equipped.

The essential features of proper superheater design, as outlined, are fulfilled in every requirement by the Babcock & Wilcox superheater as applied to Stirling boilers.

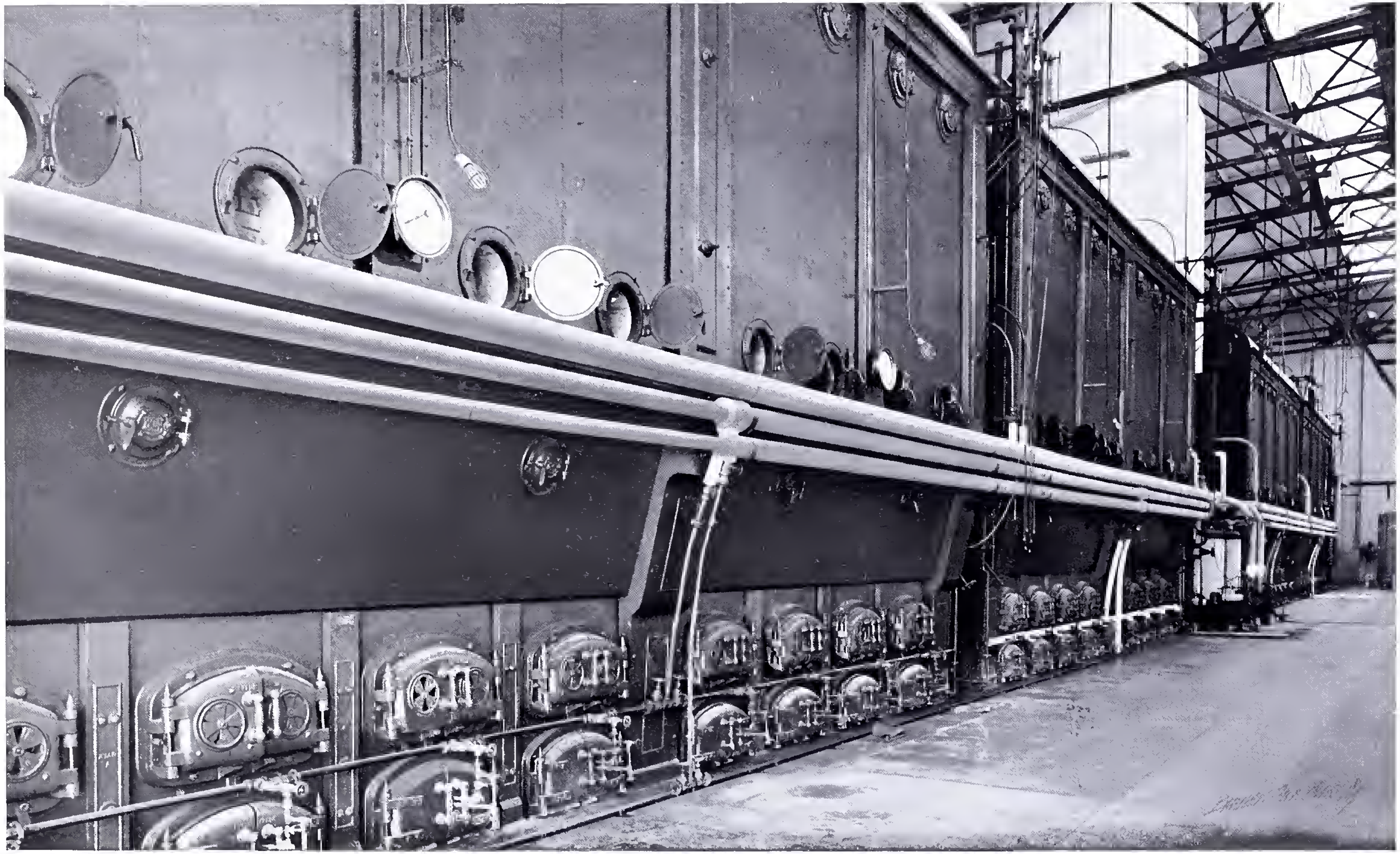
There are, in addition to the question of proper superheater design, two other factors that must be taken into consideration in the selection of a superheater. The first is the question of single responsibility for boiler and superheater installation, the arguments for which are the same as those previously discussed in the case of steel-tube economizer installations.

The second factor is the question of superheater performance, by performance meaning the amount of superheat a given superheater will produce.

It is not generally appreciated, either by the superheater manufacturer or by the average superheater user, that the number of factors affecting superheater performance is very large. While it is not the intention of the present article to go at length into a discussion of these factors,* a wide variation in superheater performance may result from a change in a single variable factor of three general sets of conditions. These conditions with the result of such change on performance may be summarized as follows:

1st. A given fuel is burned under a given boiler and superheater under constant combustion conditions, *i. e.,* a constant weight of products of combustion per pound of fuel burned, with the boiler operating at varying rates of steam output. As the capacity at which a boiler is operated is increased the increase in the weight of steam passing through the superheater is almost directly proportional to the increase in such capacity. With such an increase in capacity of boiler output, however, comes a decrease in the efficiency of heat absorption, which, since the weight of products of combustion per pound of fuel burned is a constant, means a total weight of products passing over the superheater which is increasing at a rate faster than the increase in steam output. In other words, the ratio of gas weights passing over the superheater to steam weight passing through the superheater increases with an increase of rate of steam output. Further, within limits, the furnace temperature for constant combustion conditions is approximately constant. This means that the amount of heat absorbed through direct radiation is constant, while the ratio of the heat so absorbed to the total absorption by the boiler decreases with an increase in steam output. The result of such decrease in the proportion of total absorption due to radiation is a higher gas temperature beyond the radiant heat zone and a consequent higher gas temperature entering the superheater chamber. Obviously both of these factors tend toward an increased degree of superheat with an increased rate of steam output.

*See "Steam Superheaters," a paper presented March 4, 1921, before the Engineers Club of Philadelphia.

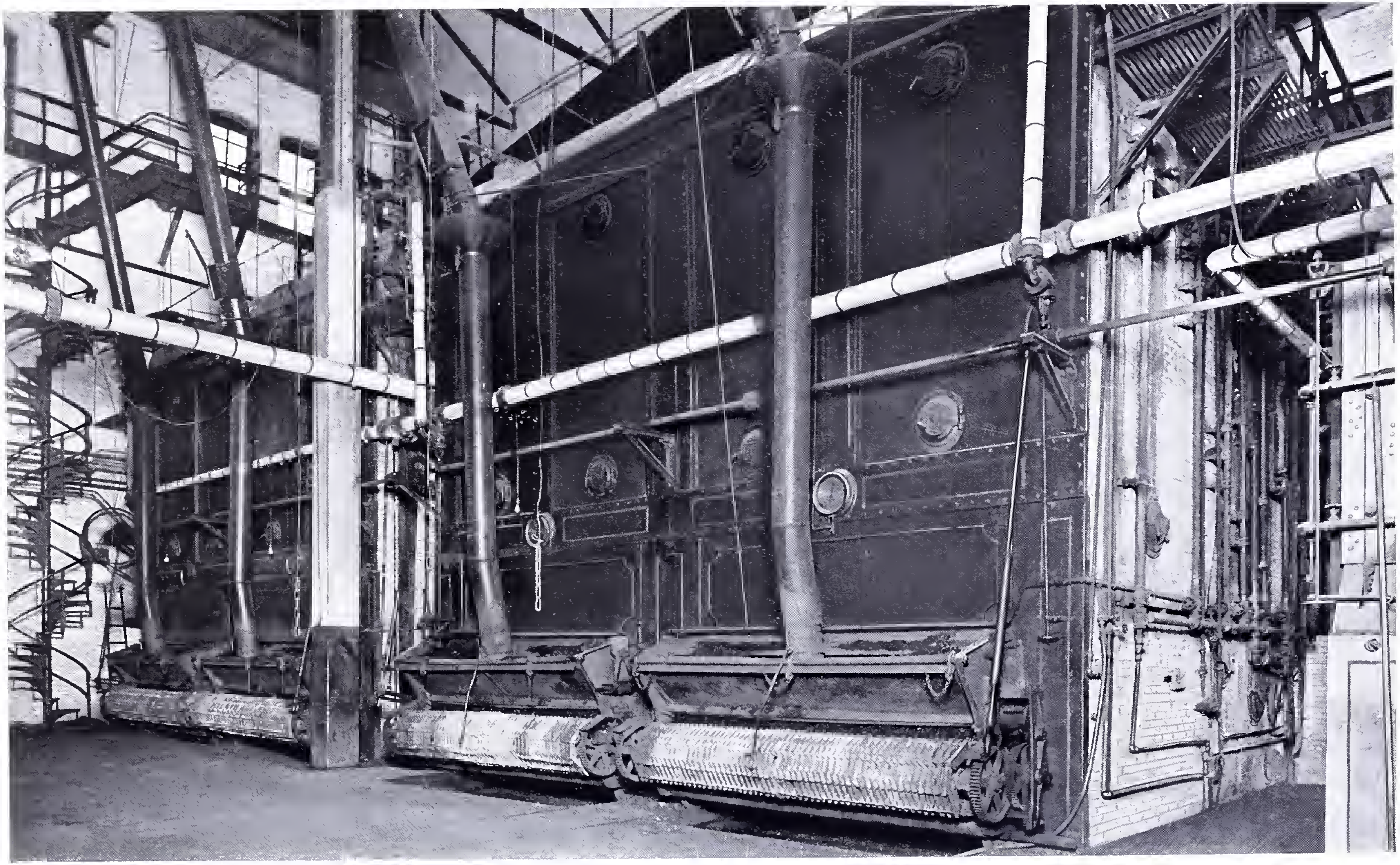


SOUTHERN CALIFORNIA EDISON CO., LONG BEACH, CAL. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 6200 HORSE POWER OF STIRLING BOILERS

2nd. The second set of conditions is one under which a given boiler and superheater are operated at a given rate of output, and a given fuel is burned, though under varying conditions of combustion. To take an extreme example, it is possible, in a properly designed furnace, with a modern type of burner, to burn blast furnace gas in such manner as to give approximately 70 pounds of products of combustion per boiler horse power developed. In ordinary practice, however, where this fuel is burned with large amounts of excess air the weight of products per pound of fuel is more commonly nearer 120 pounds per horse power developed. Under these two extremes of combustion conditions with the same fuel, for a constant weight of steam passing through the superheater, we would have a weight of gas passing over the superheater some 70 per cent greater in the case of the poor than in the case of the good conditions. Further, as under the first set of conditions, furnace temperature is also a factor in the variation in superheat. In this case, however, every variation in the amount of excess air used for combustion, or expressed as above, every variation in the weight of products of combustion per pound of fuel burned or per horse power developed, will cause a variation in furnace temperature. This in turn will affect the proportion of the total absorption due to radiation absorption, the gas temperature beyond the zone of radiant heat, and consequently the temperature of gases entering the superheater chamber.

The impossibility of obtaining the same degree of superheat from a given amount of superheating surface, even at a constant rate of steam output, under such a possible variation in combustion conditions is evident. With other fuels, a change in the combustion condition variable, while perhaps not having such a marked effect on superheater performance, may still be an appreciable factor.

3rd. The third set of conditions is one under which different fuels are burned under a given boiler and superheater, operating at a given and constant rate of steam output, with combustion conditions as nearly of equal efficiency as is possible with the fuels. The variation in superheat that will be obtained from a given superheater with a change in the fuel itself as the variable factor, is only slightly less marked than the possible variation under the second set of conditions. For example, it is entirely possible to burn oil under a boiler in such manner as to give a weight of products of combustion per boiler horse power developed as low as 38 pounds. As against this figure, which represents the best practice with oil fuel, the minimum weight of products per horse power developed that can be obtained when burning blast furnace gas by the most approved methods is some 70 pounds. In other words, for a constant weight of steam passing through the superheater, there would be more than 80 per cent more gas passing over the superheater when burning blast furnace gas than when burning oil, and when, in both instances, the fuel is burned with the highest practicable efficiency of combustion. The different furnace temperatures possible with the different fuels has the same effect on the variation of gas temperature entering the superheater chamber as in the



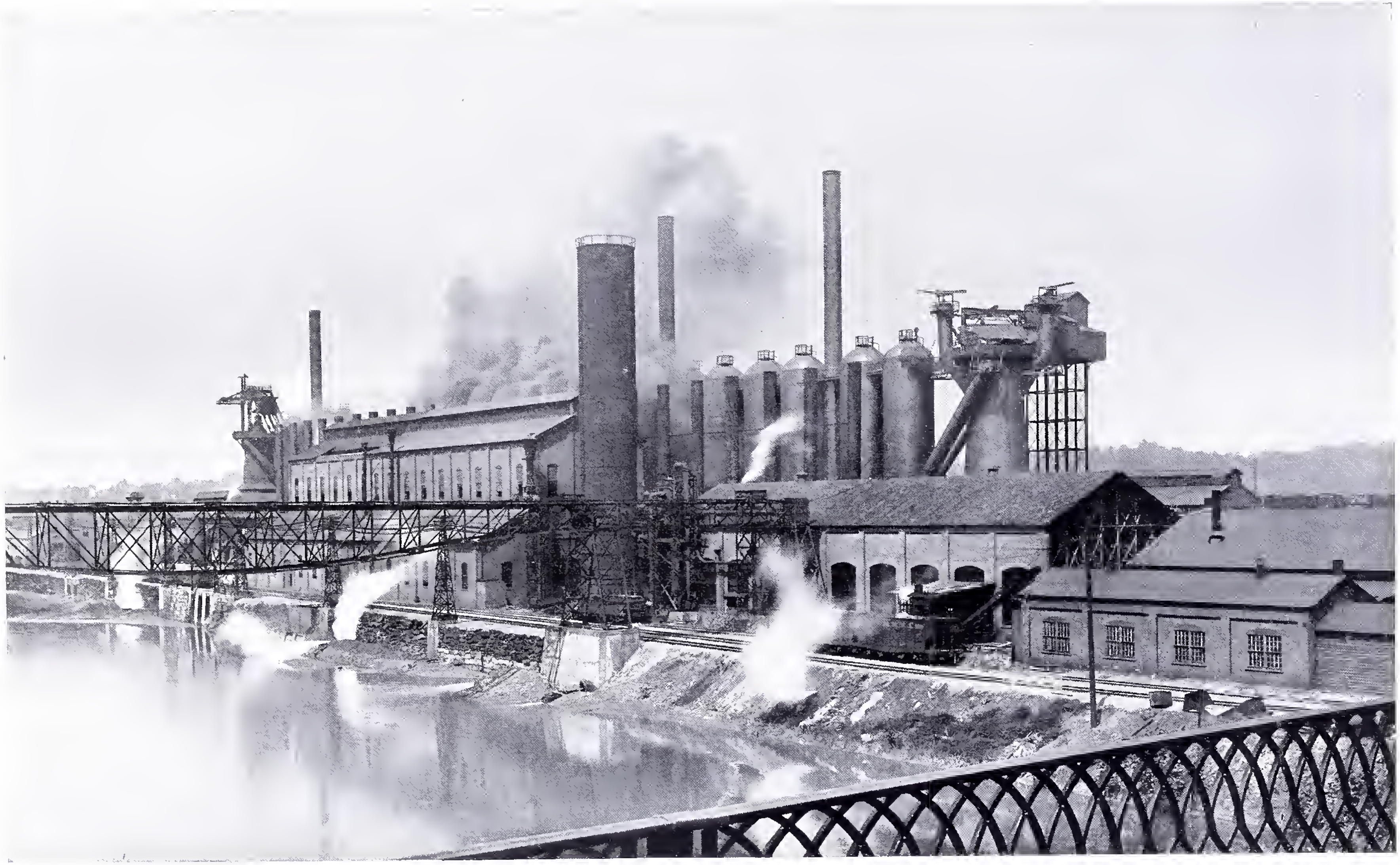
PORTION OF 3600 HORSE-POWER INSTALLATION OF STIRLING BOILERS FOR THE N. K. FAIRBANK COMPANY, CHICAGO, ILL.

first two sets of conditions considered. Clearly the superheat from a given amount of superheating surface cannot be the same with the two fuels and the boiler operating at the same output. While the fuels considered may represent the extreme variation in conditions under this assumption, any change in fuel will have the same effect on superheater performance to a greater or lesser degree.

A thorough realization of the effect of the factors discussed herein on the performance of a given superheater is essential, not only to the manufacturer who is primarily responsible for such performance, but to the superheater user who is responsible for the conditions under which the superheater is to be operated, and in designing superheaters every effort should be made to determine all of the conditions under which the superheater will be called upon to function.

Too frequently superheaters are designed and fabricated before it is possible to determine operating conditions. Either the purchaser does not know what fuel, furnace, or stoker he will use, or the capacity at which he will operate, or his ideas on the subject may change between the time of purchase and the time of installation. In the case of new installations, even with fuel, furnace, stoker and capacity known, the superheater manufacturer cannot know the operating conditions which will exist, and may design the apparatus for what are ordinarily considered average conditions for the class of plant in which the superheater is to be installed. The degree of superheat actually obtained in operation may then fall below or above the anticipated amount because of operating conditions which may be worse or better than the average.

While the reliable superheater manufacturer is not infallible when it comes to making actual and anticipated results absolutely check, it is safe to say that the manufacturer realizing to the greatest extent the effects of the factors involved on superheater performance and having the greatest opportunity and facilities for investigating the effects of such factors on performance, is the manufacturer who, in the greater percentage of instances, may be trusted to bring actual and anticipated performance most closely together.

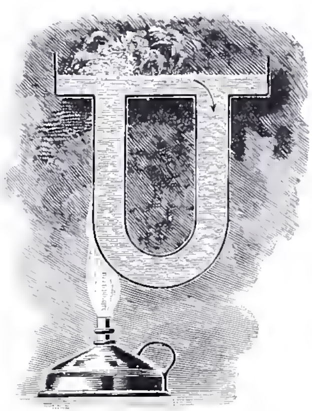


GENERAL VIEW OF FURNACE PLANT OF THE REPUBLIC IRON AND STEEL COMPANY, YOUNGSTOWN, OHIO
THIS COMPANY HAS TAKEN 58,400 HORSE POWER OF STIRLING BOILERS

CIRCULATION

A WELL DESIGNED water-tube boiler should possess to a high degree of perfection the important feature of definite and positive circulation.

The effect of different degrees of expansion in different parts of the structure, so destructive to cylindrical and tubular boilers, is eliminated in a properly designed water-tube boiler. The difference in expansion of the various parts of a boiler is dependent upon the difference in the temperature of those parts; consequently the greater the uniformity in temperature of the water the less will be the difference in expansion between the different parts of the boiler, as the temperature of the pressure parts (when the material is not too thick) must be practically the temperature of the contained water.



U-TUBE ILLUSTRATING CIRCULATION IN A PROPERLY DESIGNED WATER-TUBE BOILER

Rapid circulation insures uniformity of temperature of the water and of the pressure parts and thereby prevents unequal expansion and contraction with the consequent destructive strains.

In the Stirling boiler the rapid circulation carries the steam bubbles with the current of water to the disengaging surfaces and the steam space, and thus prevents the formation of steam pockets and the consequent overheating and burning of tubes at points where the greatest heat is applied.

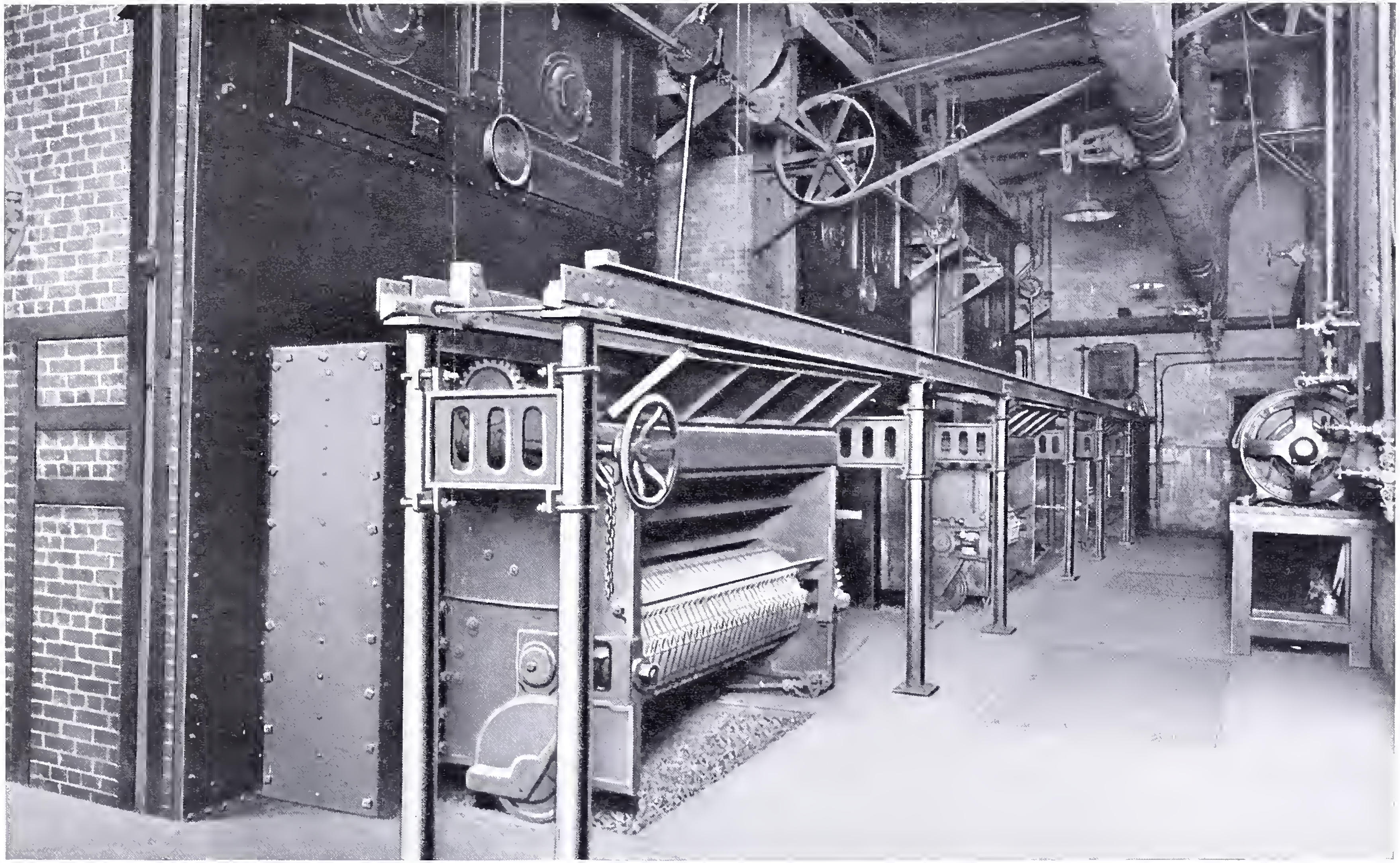
The theory of circulation, as described by Geo. H. Babcock, over thirty years ago, presents the matter in a clear and most satisfactory manner. His discussion of the subject is given in full in "Steam," one of the publications of The Babcock & Wilcox Company. The circulation is illustrated by applying the flame of a lamp to one leg of a U-tube, suspended from the bottom of a vessel filled with water, the heat from the flame setting up a uniform circulation, as indicated in the illustration. Mr. Babcock states: "This U-tube is the representation of the true method of circulation within a water-tube boiler properly constructed."

The sectional views of the Stirling water-tube boiler on preceding pages indicate that the design is such as to meet fully the requirements for uniform circulation, as illustrated by the U-tube and flame. The front bank of tubes, subjected to the most intense heat, represents the leg of the U-tube to which the flame is applied. The uniform circulation up the front bank of tubes, through the water-circulating tubes to the center steam-and-water drum and down the center bank of tubes to the mud drum, together with the downward circulation through the rear bank of tubes to replace water evaporated into steam, insures a complete and clearly defined circulation throughout the entire boiler.

STIRLING BOILERS AT THE OPEN HEARTH PLANT OF THE REPUBLIC IRON AND STEEL COMPANY, YOUNGSTOWN, OHIO, WHICH HAS BOUGHT 58,400 HORSE POWER OF STIRLING BOILERS

The steam and water-circulating tubes between the drums are designed and proportioned on the basis of information furnished by numerous tests made under service conditions. They perform a most important function in that they restrict the flow of steam and water to the extent necessary to handle highly concentrated water without priming difficulties.

As the percentages of rating at which boilers were operated were increased, the length of time for the concentration of salts in the boiler water to reach an objectionable degree was correspondingly diminished. Some feed waters that could be handled readily at low capacities began to give trouble by priming unless the amount of blow-down was excessive. As a result of long study of methods of meeting priming troubles, the rear drum of the Stirling boiler was raised to the elevation of the middle drum and steam was taken from the rear drum instead of the middle drum, as was previously standard practice. This construction enables a degree of concentration to be carried in the boiler that would undoubtedly lead, in some instances, to priming with a middle drum steam connection. That the Stirling boiler possesses this peculiar advantage is not to be taken as an advocation of higher degrees of concentration than are now usual, but should be considered rather as a safeguard during unusual conditions under which, because of feed water conditions, concentration unavoidably builds up rapidly.



S. KARPEN & BROTHERS, CHICAGO, ILL. BABCOCK & WILCOX CHAIN GRATE STOKERS INSTALLED WITH 900 HORSE POWER OF STIRLING BOILERS

THE STIRLING BOILER IN SERVICE

STIRLING boilers have been in operation since 1890, and their performance since that time has clearly demonstrated their right to all of the claims of excellence which have been made for them. Repeat orders are so frequent that a list of them, eliminating names of companies that have placed less than three orders, would fill many pages of this book.

The favorable regard shown for this boiler became even more marked during the stress of the World War, when practically every industrial boiler plant was driven to its highest capacity and at the same time economy in the use of coal was imperative. The value of the free circulation in the Stirling boiler was then proved in many plants by its repeatedly demonstrated ability to carry heavy loads for long periods without substantial drop in fuel economy, while the facility with which the baffles can be rearranged to meet new fuel and draft conditions was a great help in many cases in maintaining economical performance after great changes in the fuel or a new boiler was connected to a chimney serving other boilers.

These merits of the Stirling boiler are not to be learned from an examination of the records of boiler tests. Many such tests of this boiler have been made, showing its performance under a great variety of conditions and with many grades of fuel. A few of these records are printed on pages 101 to 105, not as showing what the boiler can do when operated with exceptional care for a few hours but to indicate what good boiler-room management can accomplish with various fuels and with boilers operated at different percentages of rating.

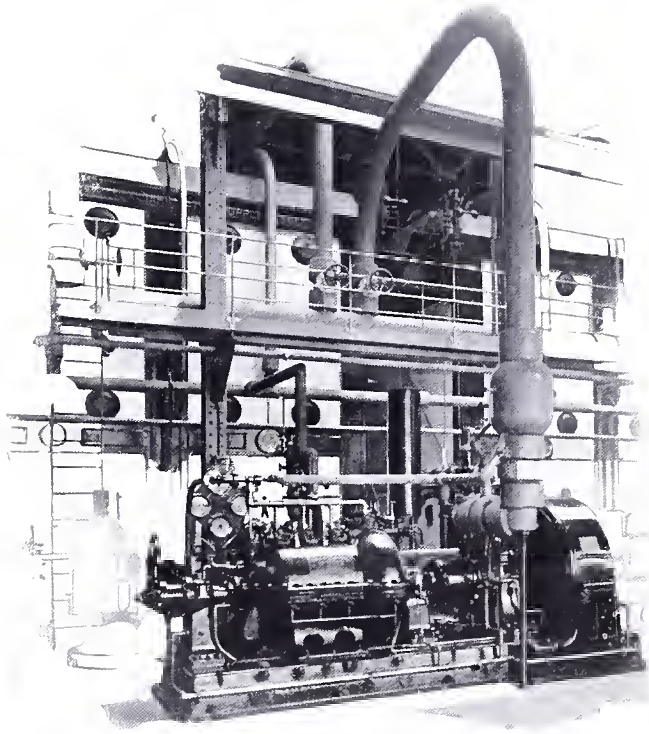
The ease with which the Stirling boiler can be cleaned, its efficient and substantial baffling, and its flexibility under varying load conditions have caused it to be adopted extensively in plants representing every industry. On January 1, 1921, over 5,600,000 horse power of Stirling boilers were in use at electric light and power plants, street railway power stations, coal mines, blast furnaces, rolling mills, smelting and refining works, office and other large buildings, sugar mills, ice plants, textile mills, oil refineries, lumber mills, pulp and paper mills, water works, flour mills, packing houses, machine shops, printing plants, rubber works, the power stations of steam railways, and a long list of mills, shops and buildings in allied industries.

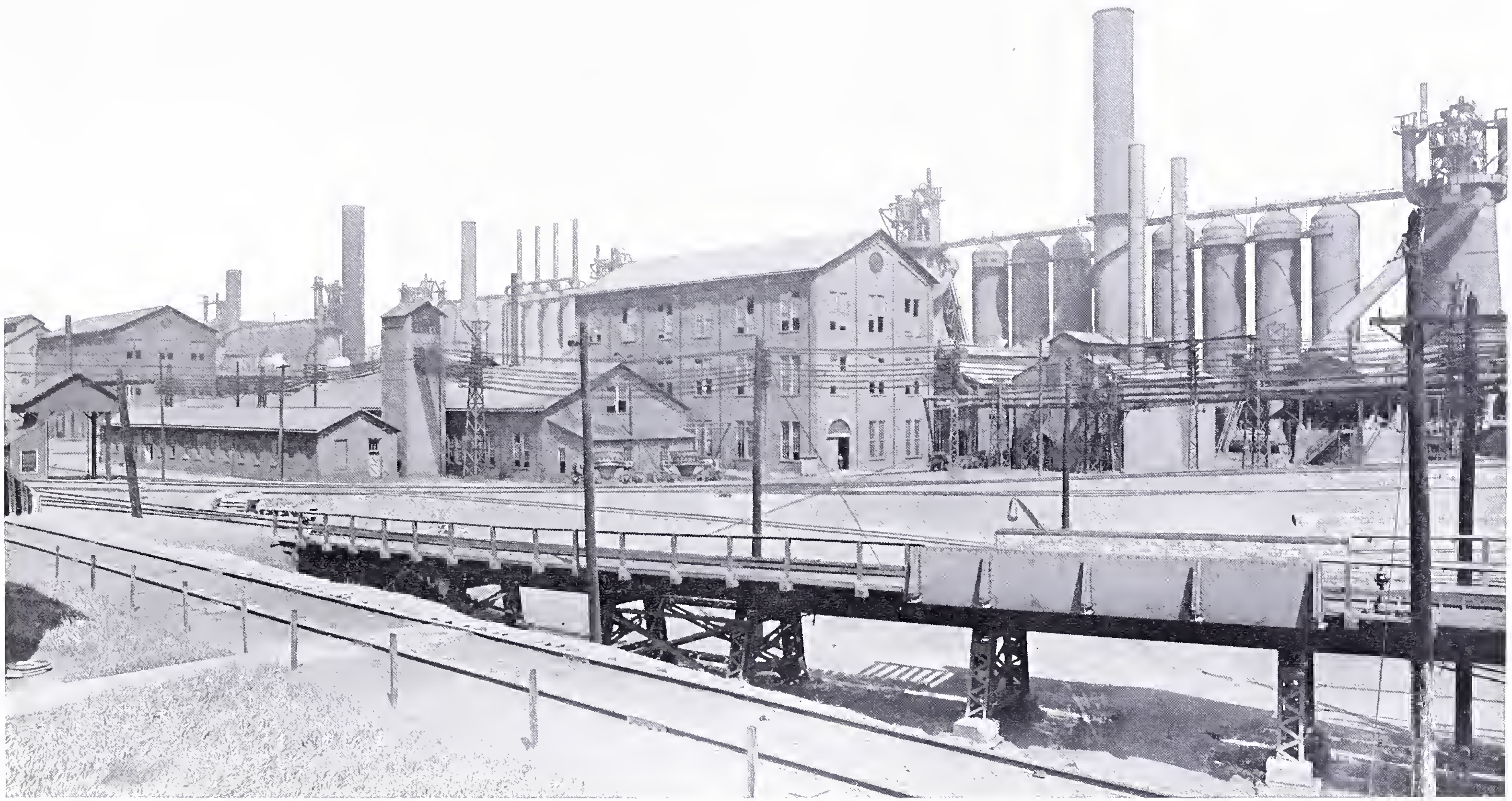
The Stirling boiler has proved entirely successful in the use of anthracite and bituminous coal with both hand and stoker firing, lignite from the various sources of this fuel, powdered coal, oil, wood and saw-mill refuse, green bagasse, tan bark, blast furnace and coke oven gas, natural gas and waste heat.

Experience with many thousands of Stirling boilers under all kinds of operating conditions and using every kind of fuel proves conclusively that the selection of a water-tube boiler, to be most satisfactory, must be governed by good

MERCHANTS HEAT AND LIGHT COMPANY, INDIANAPOLIS, IND., OPERATING
8500 HORSE POWER OF STIRLING BOILERS

judgment based on highly specialized knowledge of boiler performance. There is no class of service or fuel to which the Stirling boiler has not demonstrated its adaptability in an entirely satisfactory manner, particularly when the long experience of its builders is utilized in selecting the class and size of the units used.





OHIO WORKS, CARNEGIE STEEL COMPANY, YOUNGSTOWN. THIS COMPANY HAS BOUGHT 96,700 HORSE POWER OF STIRLING BOILERS

CARE AND MANAGEMENT OF THE STIRLING BOILER

BEFORE placing a new boiler in service a careful and thorough examination should be made of the pressure parts and the setting. The latter should be inspected to see that the baffle openings and the distance from the arch to the tubes are as called for by the particular drawings for the installation in question; that the joints of the baffle tile are directly behind the tubes; that the mud drum and blow-off pipe are free to expand without interference with the setting walls; and that all brick and mortar are cleaned from the setting and pressure parts. Tie rods should be set up snug and then slacked slightly until the setting has been thoroughly warmed after the first firing. Internally the boiler should be examined to insure the absence of dirt, waste, oil and tools.

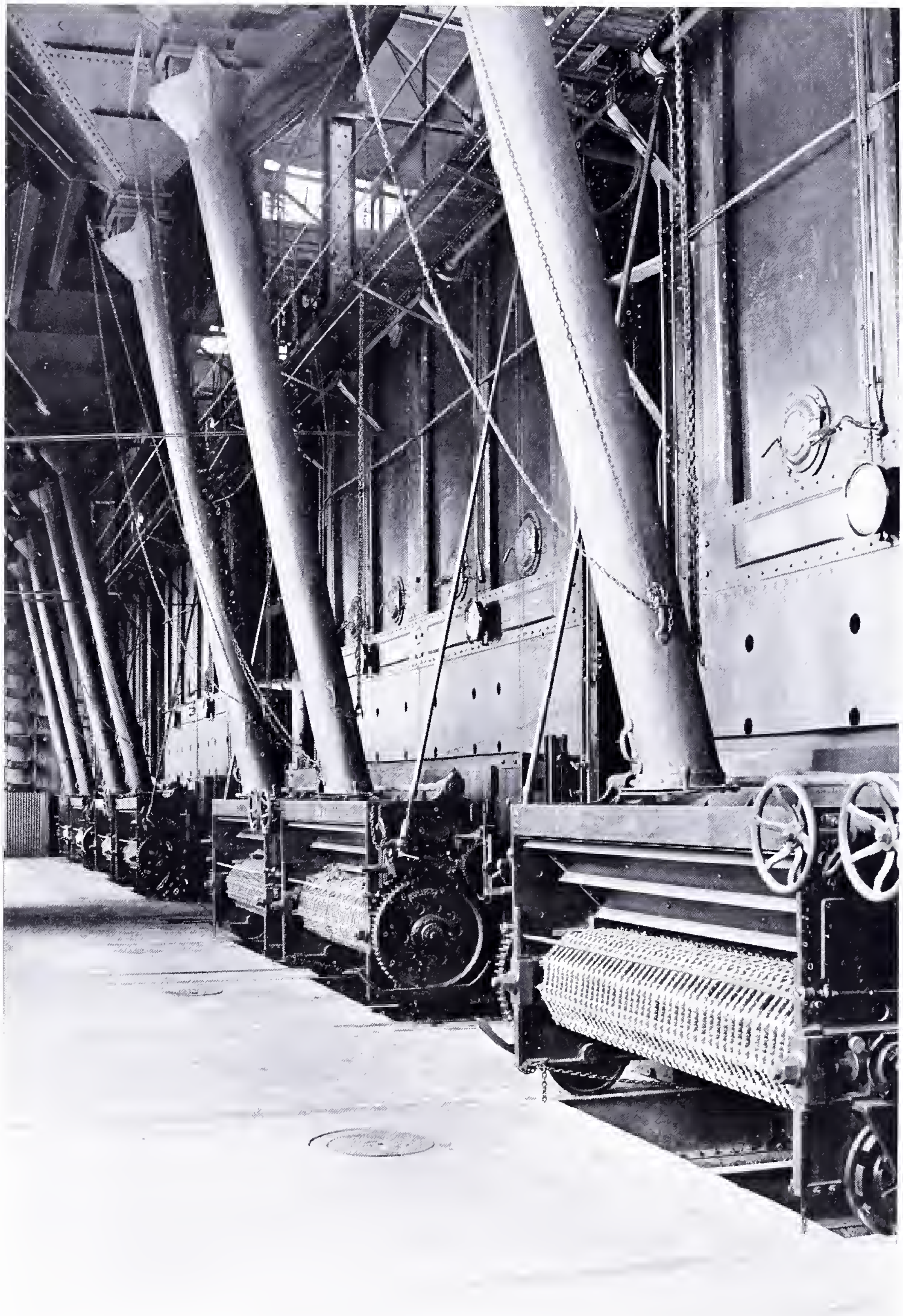
If there is oil or paint in the boiler, one peck of soda ash should be placed in each upper drum, the boiler filled to its normal level with water and a slow fire started. After twelve hours the fire should be allowed to die out, the boiler cooled slowly, then opened and washed out thoroughly. This will remove all oil and grease from the interior of the boiler and prevent foaming when it is placed in service.

The water column piping should be examined and known to be free and clear, and the water level as indicated by the gauge glass should be checked by opening the gauge cocks.

Firing the boiler with green walls will invariably crack the setting brickwork unless this be dried properly. To start this drying process, as soon as the brickwork is completed the damper and ash-pit doors should be blocked open to maintain a circulation of air through the setting. Whenever possible, this should be done for several days before firing. When ready for firing, wood should be used for a light fire, gradually building it up until the walls are thoroughly warmed. Coal should then be fired and the boiler placed in regular service.

A boiler should not be cut into the line with other boilers until the pressure is within a few pounds of that in the steam main. The boiler stop valve should be opened very slowly until it is opened fully. Care must be taken to see that the arrangement of piping is such that there will be no possibility of water collecting in any pocket between a boiler and the main, from which it can be carried over into the steam line when the boiler is cut in.

In regular operation the safety valve and the steam gauge should be checked daily. The steam pressure should be raised sufficiently to cause the safety valves to blow, at which time the steam gauge should indicate the pressure for which the safety valves are known to be set. If it does not, one is in error and the gauge should at once be compared with one of known accuracy and any discrepancy rectified. The water column should be blown down thoroughly at least



EDWARD FORD PLATE GLASS CO., ROSSFORD, OHIO. THIS COMPANY HAS BOUGHT 9900 HORSE POWER OF STIRLING BOILERS

once on each shift and the height of the water as shown by the gauge glass checked by opening the gauge cocks at the side of the column. The bottom blow-off valves should be kept tight and opened at least once daily to blow from the mud drum any sediment which may have collected from concentration of the boiler feed water. The amount of blowing necessary will depend upon the character of the feed water used.

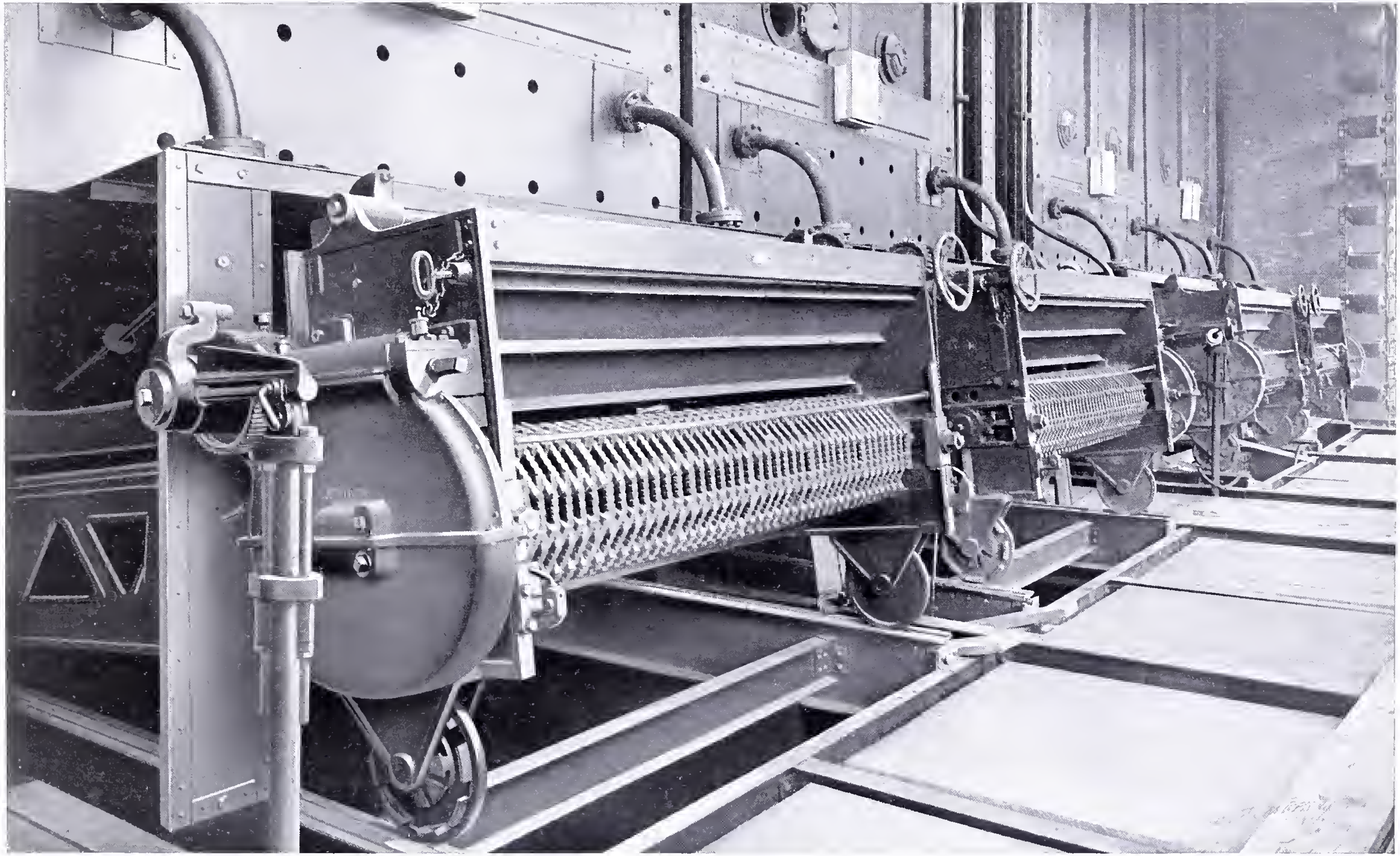
In case of low water, resulting either from carelessness or unforeseen conditions of operating, the essential object to be obtained is to extinguish the fire in the quickest possible manner. Ordinary practice has been to cover the fires with wet ashes, dirt or fresh fuel. Under certain conditions it is feasible to put out the fires with a heavy stream of water from a hose and this method, where practicable, should be followed. The boiler should be cut out of the line and a thorough inspection made to ascertain what damage, if any, has been done before it is again placed in operation.

FIG. 1

The efficiency and capacity of a boiler depend to an extent very much greater than is ordinarily appreciated upon its cleanliness internally and externally, and systematic cleaning should be included as a regular feature in the operation of any steam plant.

The outer surfaces of the tubes should be blown free from soot with a steam lance at regular intervals, the frequency of such cleaning periods depending upon the class of fuel burned. Internally the tubes should be kept clean from scale and sludge which will accumulate due to the concentration of solids present in practically any boiler feed water. This internal cleaning can best be accomplished by the use of an air or water-driven turbine, the cutter heads of which may be changed to handle varying thicknesses of scale. The illustration on this page shows a turbine cleaner which has been found to give satisfactory results.

When scale has been allowed to accumulate to an excessive thickness the work of removing it is difficult. Where the scale is of sulphate formation its removal may be made easier by filling the boiler with water in which there has



STIRLING BOILERS AND BABCOCK & WILCOX STOKERS, PITCAIRN SHOPS, PENNSYLVANIA RAILROAD CO., WHICH HAS BOUGHT 9200 HORSE POWER OF STIRLING BOILERS

been placed a bucketful of soda ash to each drum, starting a slow fire and allowing the water to boil for twenty-four hours without allowing any pressure on the boiler. It should then be cooled slowly, drained, and the turbine cleaner used immediately as the action of the air tends to harden the scale. While the use of a boiler compound in feed water is permissible with a view to preventing the formation of scale, such an agent should not be introduced into the boiler while it is in operation with a view to softening or loosening any scale that may already be present in the boiler.

Aside from the aspect of efficiency and capacity, a clean interior of boiler heating surfaces insures protection from burning. In the absence of a blow-pipe action of the flames, it is impossible to burn a metal surface when water is in intimate contact with that surface. Any formation of scale on the interior surfaces of a boiler will keep the water from those surfaces and increase their tendency to burn. Particles of loose scale which may have become detached will lodge at certain points in the tubes and act at such points in the same manner as a continuous coating of scale except that the tendency to burn is localized. If oil is allowed to enter the boiler with the feed water, its action will be the same as that of scale in keeping the water from the metal of the tubes, in this way increasing their liability to burn.

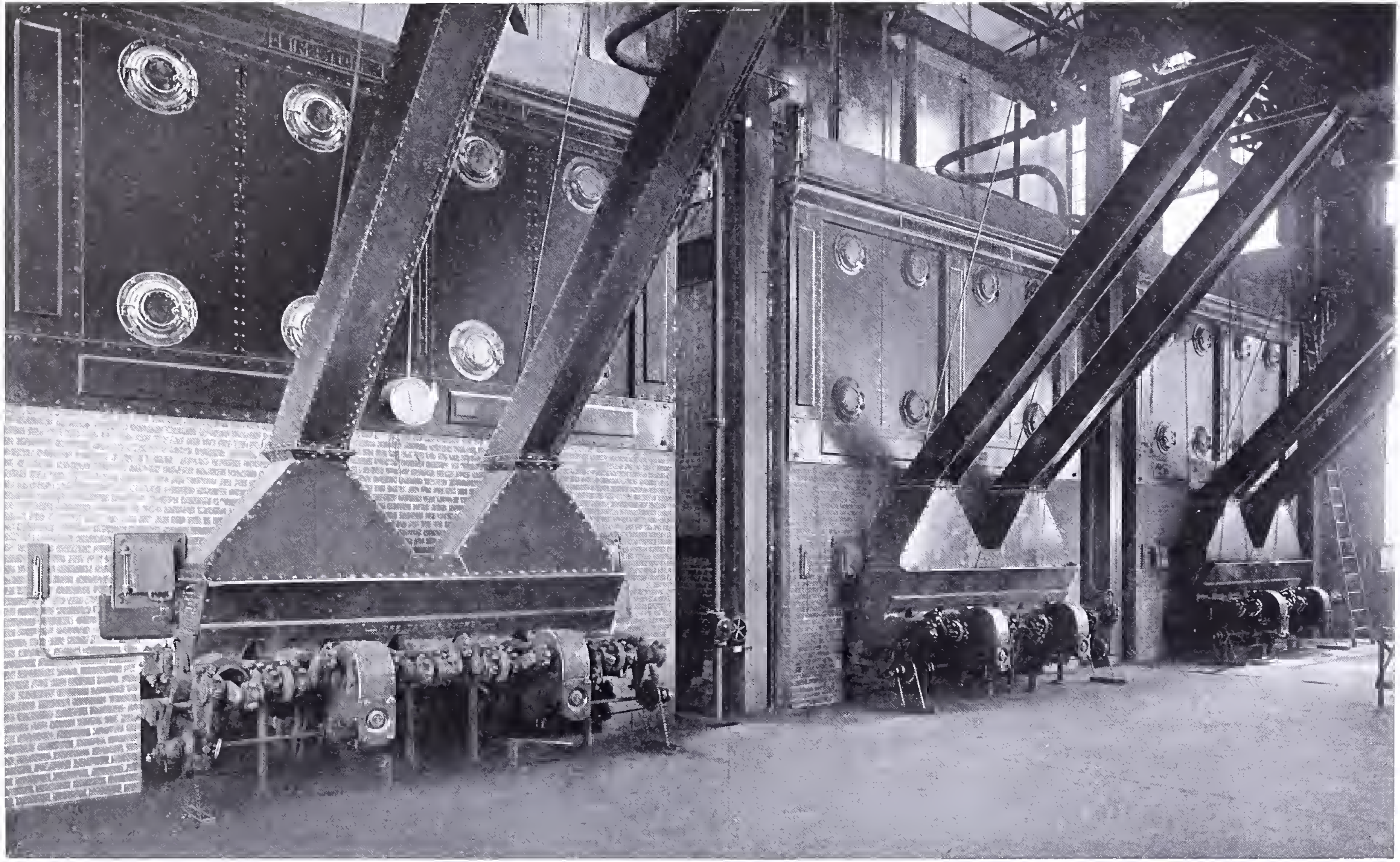
It has been proven beyond doubt that a very large percentage of tube losses is due to the presence of scale which, in many instances has been so thin as to be considered of no moment, and the importance of maintaining the interior of boiler heating surfaces in a clean condition cannot be emphasized too strongly.

If pitting or corrosion is noted, the parts affected should be carefully cleaned and painted with white zinc. The cause of such action should be determined immediately and steps taken to see that a proper remedy is applied.

When making an internal inspection of a boiler or when cleaning the interior of the heating surfaces, great care must be taken to guard against the possibility of steam entering the boiler in question from any other boilers on the line through open blow-off valves or through the careless opening of the boiler stop valve. Bad cases of scalding have resulted from neglect of this precaution.

Boilers should be taken out of service at regular intervals for cleaning and repairs. When this is done, the boiler should be allowed to cool slowly and when possible allowed to stand twelve hours after the fires are drawn before opening. The cooling process should not be hastened by causing cold air to rush through the setting as this will cause difficulties with the setting brickwork. While the boiler is off for cleaning, a careful examination should be made of its condition, both internally and externally, and all leaks of steam, water and air through the setting should be stopped promptly.

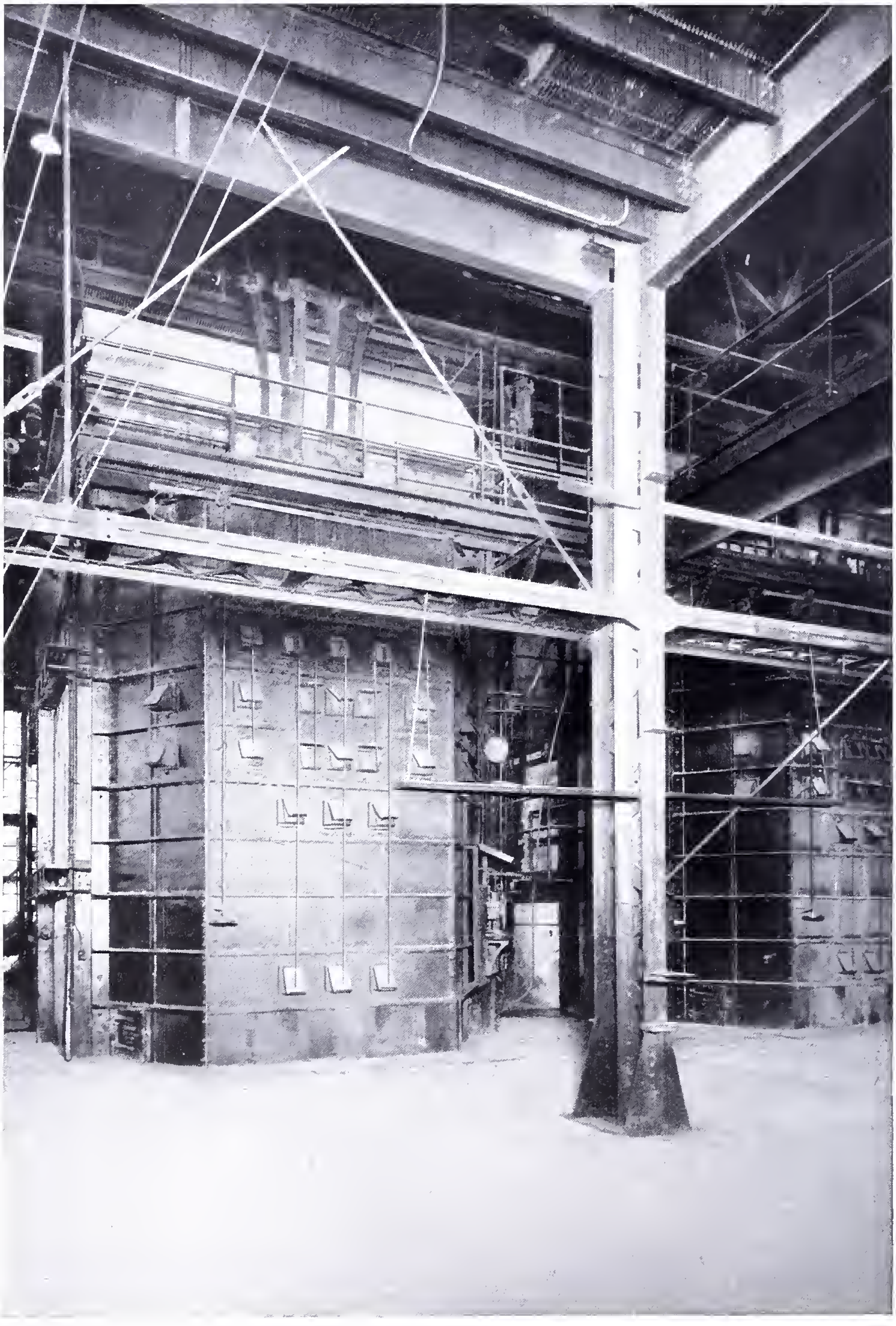
If a boiler is to remain idle for some time it is liable to deteriorate much faster than when in service. If the period for which it is to be laid off is not to exceed three months it may be filled with water while out of service. The boiler



PORTION OF AN INSTALLATION OF STIRLING BOILERS FOR THE FIRESTONE TIRE AND RUBBER COMPANY, AKRON, OHIO, WHICH HAS BOUGHT 11,700 HORSE POWER IN ALL

should be thoroughly cleaned, internally and externally, all soot and ashes being removed from the setting and any accumulation of scale removed from the interior surfaces. It should then be filled with water to which about four buckets of soda ash has been added, a very light fire started to drive the air from the water, the fire then allowed to die out and the boiler pumped full.

If the boiler is to be out of service for more than three months, it should be emptied, cleaned and thoroughly dried. A tray of quicklime should be placed in each drum, the boiler closed up, the grates covered and a quantity of quicklime placed on these. Special care must be taken to prevent air, steam or water leaks into the setting or onto the pressure parts, to obviate danger of corrosion.



ONE OF THE 768 HORSE-POWER STIRLING BOILERS FIRED WITH POWDERED COAL, AT THE RIVER MINES STATION OF THE ST. JOSEPH LEAD CO.

BOILER FEED WATER

ALL natural waters contain some impurities which, when introduced into a boiler may appear as solids. In view of the apparent present-day tendency toward large size boiler units and high overloads, the importance of the use of pure water for boiler feed purposes cannot be over-estimated.

Ordinarily, when water of sufficient purity for such use is not at hand, the supply available may be rendered suitable by some process of treatment. Against the cost of such treatment, there are many factors to be considered. With water in which there is a marked tendency toward scale formation, the interest and depreciation on the added boiler units necessary to allow for the systematic cleaning of certain units must be taken into consideration. Again there is a considerable loss in taking boilers off for cleaning and replacing them on the line. On the other hand, the decrease in capacity and efficiency accompanying an increased incrustation of boilers in use has been too generally discussed to need repetition here. Many experiments have been made and actual figures reported as to this decrease, but in general such figures apply only to the particular set of conditions found in the plant where the boiler in question was tested. So many factors enter into the effect of scale on capacity and economy that it is impossible to give any accurate figures on such decrease that will serve all cases, but that it is large has been thoroughly proven.

While it is almost invariably true that practically any cost of treatment will pay a return on the investment in the apparatus, the fact must not be overlooked that there are certain waters which should never be used for boiler feed purposes

TABLE 1

APPROXIMATE CLASSIFICATION OF IMPURITIES FOUND IN FEED WATERS. THEIR EFFECT AND ORDINARY METHODS OF RELIEF

Difficulty Resulting from Presence of	Nature of Difficulty	Ordinary Method of Overcoming or Relieving
Sediment, Mud, etc.	Incrustation	Settling tanks, filtration, blowing down.
Readily Soluble Salts	Incrustation and Priming	Blowing down.
Bicarbonates of Lime, Magnesia, etc.	Incrustation	Heating feed. Treatment by addition of lime or of lime and soda. Barium carbonate.
Sulphate of Lime	Incrustation	Treatment by addition of soda. Barium carbonate.
Chloride and Sulphate of Magnesium	Corrosion	Treatment by addition of carbonate of soda.
Acid	Corrosion	Alkali.
Dissolved Carbonic Acid and Oxygen	Corrosion	Heating feed. Keeping air from feed. Addition of caustic soda or slacked lime.
Grease	Corrosion	Filter. Iron alum as coagulant. Neutralization by carbonate of soda. Use of best hydrocarbon oils.
Organic Matter	Corrosion	Filter. Use of coagulant.
Organic Matter (Sewage)	Priming	Settling tanks. Filter in connection with coagulant.
Carbonate of Soda in large quantities	Priming	Barium carbonate. New feed supply. If from treatment, change.
Sodium Salts	Priming	Blowing down. New feed supply.

YABUCOA SUGAR COMPANY, SAN JUAN, PORTO RICO, OPERATING 1770 HORSE POWER OF STIRLING BOILERS

and which no treatment can render suitable for such purpose. In such cases, the only remedy is the securing of other feed supply or the employment of evaporators for distilling the feed water as in marine service.

It is evident that the whole subject of boiler feed waters and their treatment is one for the chemist rather than for the engineer. A brief outline of the difficulties that may be experienced from the use of poor feed water and a suggestion as to a method of overcoming certain of these difficulties is all that will be attempted here. Such a brief outline of the subject, however, will indicate the necessity for a chemical analysis of any water before a treatment is tried and the necessity of adapting the treatment in each case to the nature of the difficulties that may be experienced.

Table 1 gives a list of impurities which may be found in boiler feed water, grouped according to their effect on boiler operation and giving the customary method used for overcoming the difficulty to which they lead.

Scale—Scale is formed on boiler heating surfaces by the depositing of impurities in the feed water in the form of a more or less hard adherent crust. Such deposits are due to the fact that water loses its soluble power at high temperatures or because the concentration becomes so high, due to evaporation, that the impurities crystallize and adhere to the boiler surfaces. The opportunity for formation of scale in a boiler will be apparent when it is realized that during a month's operation of a 100 horse-power boiler, 300 pounds of solid matter may be deposited from water containing only 7 grains per gallon, while some spring and well waters contain sufficient to cause a deposit of as high as 2000 pounds.

The salts usually responsible for such incrustation are the carbonates and sulphates of lime and magnesia, and boiler feed treatment in general deals with the getting rid of these salts more or less completely.

Table 2 gives the solubility of these mineral salts in water at various temperatures in grains per U. S. gallon (58,381 grains). It will be seen from this table that the carbonates of lime and magnesium are not soluble above 212 degrees, and calcium sulphate, while somewhat insoluble above 212 degrees, becomes more greatly so as the temperature increases.

TABLE 2

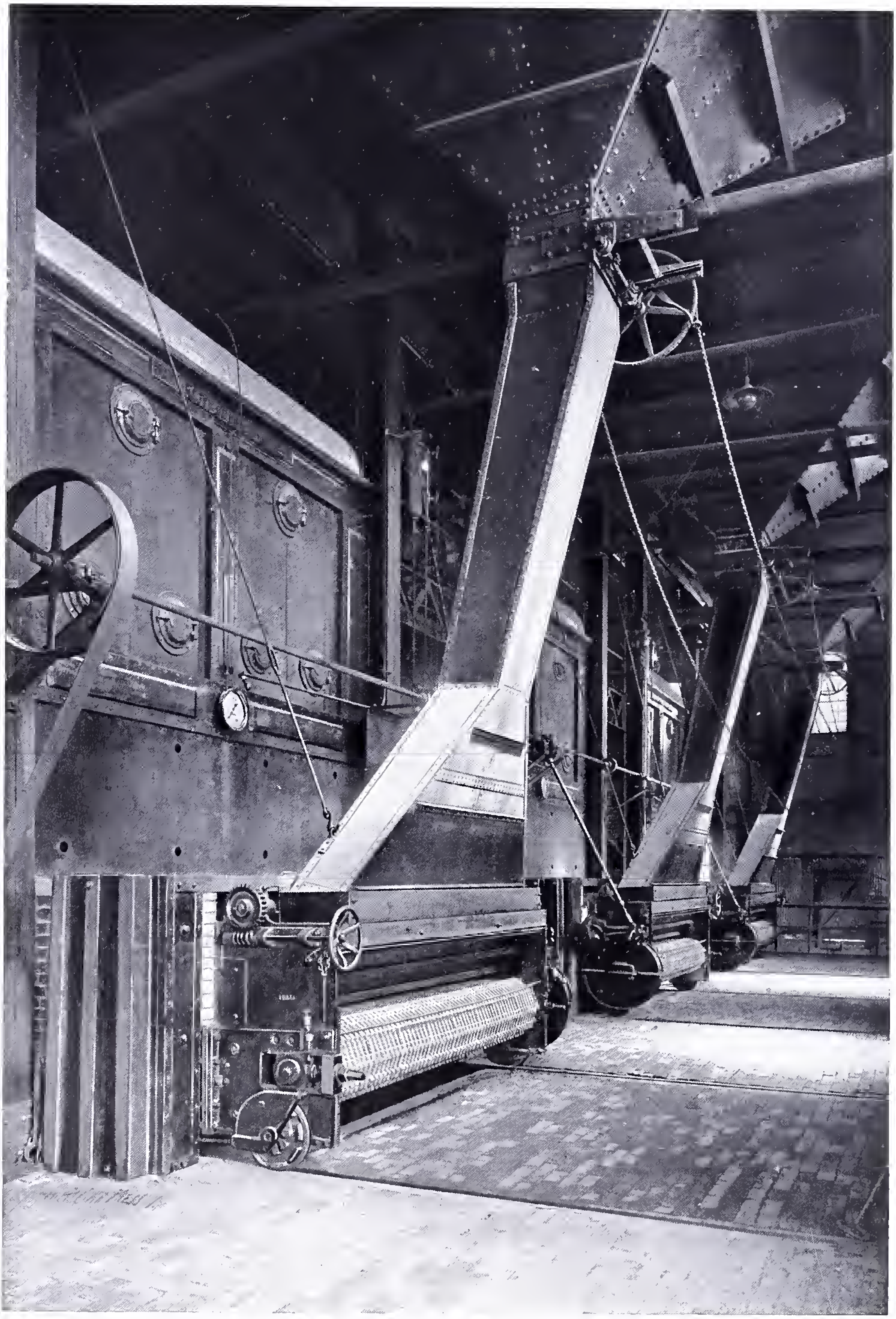
SOLUBILITY OF MINERAL SALTS IN WATER (SPARKS)

IN GRAINS PER U. S. GALLON (58,381 GRAINS), EXCEPT AS NOTED

Temperature Degrees Fahrenheit	60 Degrees	212 Degrees
Calcium Carbonate	2.5	1.5
Calcium Sulphate	140.0	125.0
Magnesium Carbonate	1.0	1.8
Magnesium Sulphate	3.0 pounds	12.0 pounds
Sodium Chloride	3 5 pounds	4.0 pounds
Sodium Sulphate	1.1 pounds	5.0 pounds

CALCIUM SULPHATE AT TEMPERATURES ABOVE 212 DEGREES (CHRISTIE)

Temperature, degrees Fahrenheit	284	329	347–365	464	482
Corresponding gauge pressure	38	87	115–149	469	561
Grains per gallon	45.5	32.7	15.7	10.5	9 3



NEWPORT ROLLING MILL CO., NEWPORT, KY., 1530 HORSE POWER OF STIRLING BOILERS EQUIPPED WITH BABCOCK & WILCOX CHAIN GRATE STOKERS

Scale is also formed by the settling of mud and sediment carried in suspension in water. This may bake or be cemented to a hard scale when mixed with other scale-forming ingredients.

Corrosion—Corrosion, or a chemical action leading to the actual destruction of the boiler metal, is due to the solvent or oxidizing properties of the feed water. It results from the presence of acid, either free or developed* in the feed, the admixture of air with the feed water, or as a result of galvanic action. In boilers it takes several forms:

1st. Pitting, which consists of isolated spots of active corrosion which does not attack the boiler as a whole.

2nd. General corrosion, produced by naturally acid waters and where the amount is so even and continuous that no accurate estimate of the metal eaten away may be made.

3rd. Grooving, which, while largely a mechanical action which may occur in neutral waters, is intensified by acidity.

Foaming—This phenomenon, which ordinarily occurs with waters contaminated with sewage or organic growths, is due to the fact that the suspended particles collect on the surface of the water in the boiler and render difficult the liberation of steam bubbles arising to that surface. It sometimes occurs with water containing carbonates in solution in which a light flocculent precipitate will be formed on the surface of the water. Again, it is the result of an excess of sodium carbonate used in treatment for some other difficulty where animal or vegetable oil finds its way into the boiler.

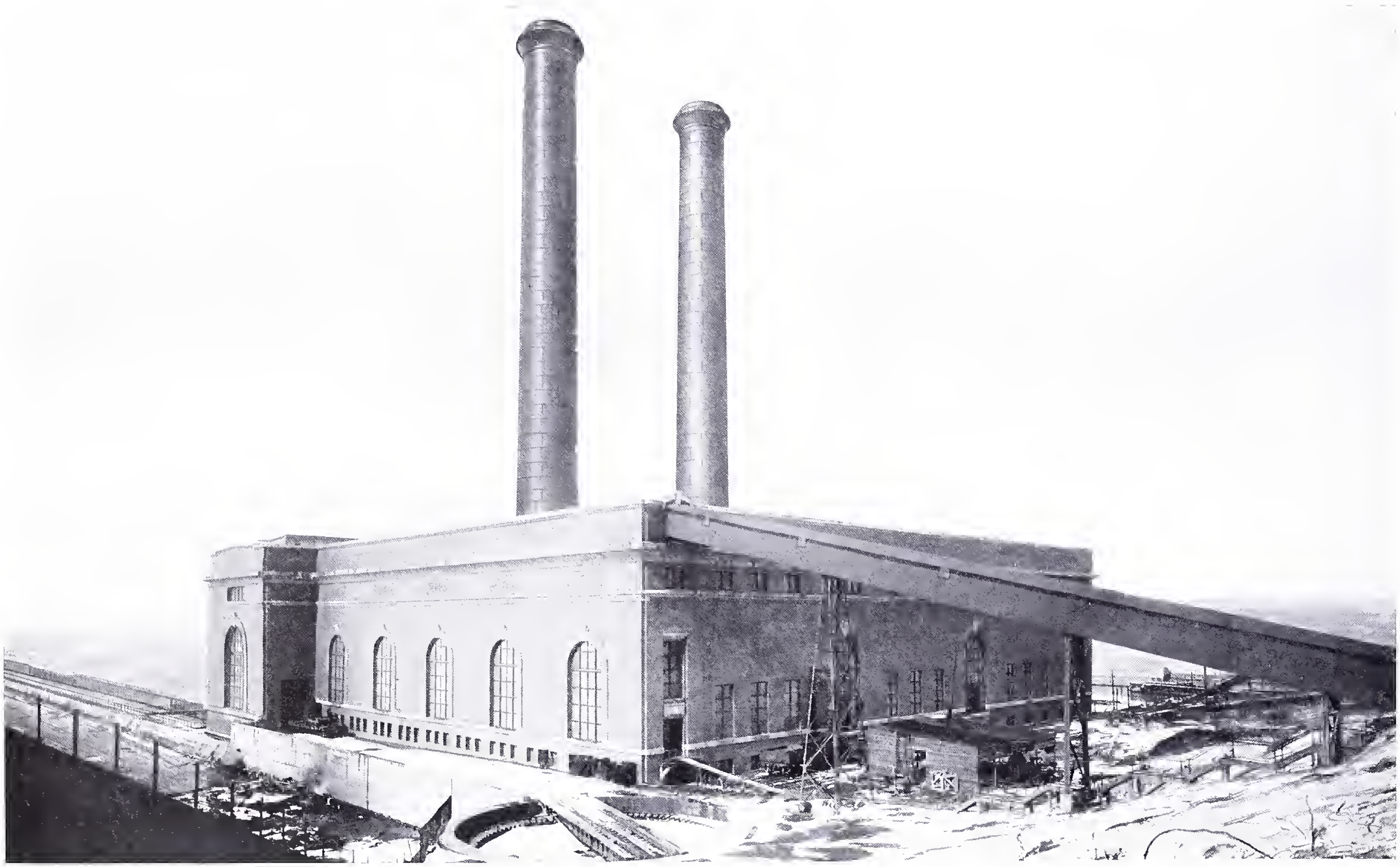
Priming—Priming, or the passing off of steam from a boiler in belches, is caused by the concentration of sodium carbonate, sodium sulphate or sodium chloride in solution. Sodium sulphate is found in many southern waters and also where calcium or magnesium sulphate is precipitated with soda ash.

Treatment of Feed Water—For scale formation. The treatment of feed water, carrying scale-forming ingredients, is along two main lines: 1st, by chemical means by which such impurities as are carried by the water are caused to precipitate; and 2nd, by the means of heat, which results in the reduction of the power of water to hold certain salts in solution. The latter method alone is sufficient in the case of certain temporarily hard waters, but the heat treatment, in general, is used in connection with a chemical treatment to assist the latter.

Before going further into detail as to the treatment of water, it may be well to define certain terms used.

Hardness, which is the most widely known evidence of the presence in water of scale-forming matter, is that quality, the variation of which makes it more

*Some waters, not naturally acid, become so at high temperatures, as when chloride of magnesia decomposes with the formation of free hydrochloric acid; such phenomena become more serious with an increase in pressure and temperature.



GENERAL VIEW OF THE LAKE SHORE STATION OF THE CLEVELAND ELECTRIC ILLUMINATING CO., CLEVELAND, OHIO

difficult to obtain a lather or suds from soap in one water than in another. This action is made use of in the soap test for hardness described later. Hardness is ordinarily classed as either temporary or permanent. Temporarily hard waters are those containing bicarbonates of lime and magnesium which may be precipitated by boiling at 212 degrees and which, if they contain no other scale-forming ingredients, become "soft" under such treatment. Permanently hard waters are those containing mainly calcium sulphate, which is only precipitated at the high temperatures found in the boiler itself, 300 degrees Fahrenheit or more. The scale of hardness is an arbitrary one, based on the number of grains of solids per gallon, and waters may be classed on such a basis as follows: 1-10 grains per gallon, soft water; 10-20 grains per gallon, moderately hard water; above 25 grains per gallon, very hard water.

Alkalinity is a general term used for waters containing compounds with the power of neutralizing acids.

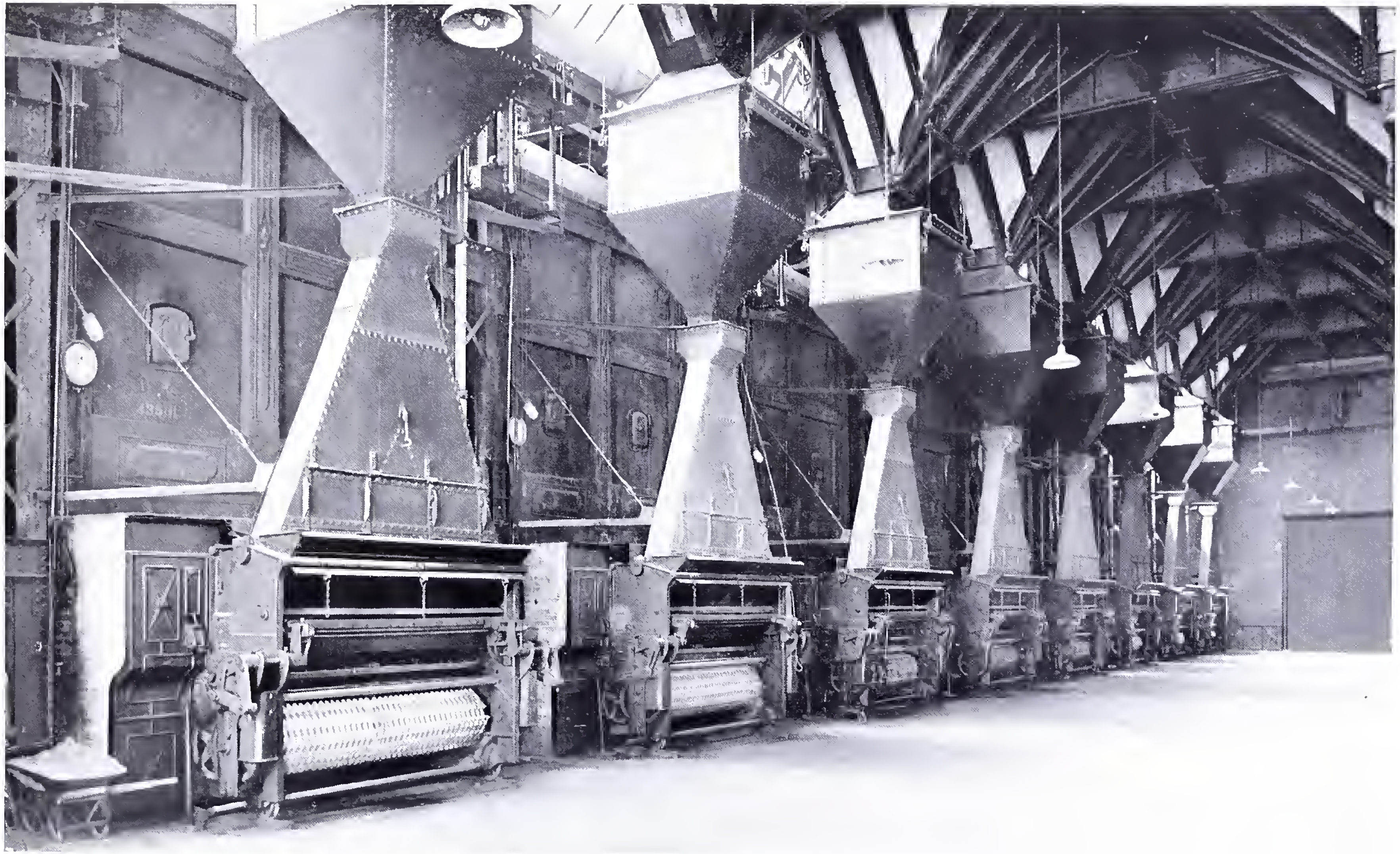
Causticity, as used in water treatment, is a term coined by A. McGill, indicating the presence of an excess of lime or caustic soda added during treatment. Though such presence would also indicate alkalinity, the term is arbitrarily used to apply to those hydrates whose presence is indicated by phenolphthalein.

Of the chemical methods of water treatment, there are five general processes:

1st. *Lime Process*—The lime process is used for waters containing bicarbonates of lime and magnesia. Slacked lime in solution, as lime water, is the reagent used. This combines with the carbonic acid which is present, either free or as bicarbonates, to form an insoluble carbonate of lime. The soluble bicarbonates of lime and magnesia, losing their carbonic acid, thereby become insoluble and precipitate.

2nd. *Soda Process*—The soda process is used for waters containing sulphates of lime and magnesia. Carbonate of soda and hydrate of soda (caustic soda) are used either alone or together as the reagents. Carbonate of soda, added to water containing little or no carbonic acid or bicarbonates, decomposes the sulphates to form insoluble carbonate of lime or magnesia which precipitate, the neutral soda remaining in solution. If free carbonic acid or bicarbonates are present, bicarbonate of lime is formed and remains in solution, though under the action of heat, the carbon dioxide will be driven off and insoluble monocarbonates will be formed. Caustic soda used in this process causes a more energetic action, it being presumed that the caustic soda absorbs the carbonic acid, becomes carbonate of soda and acts as above.

3rd. *Lime and Soda Process*—This process, which is the combination of the first two, is by far the most generally used in water purification. Such a method is used where sulphates of lime and magnesia are contained in the water, together with such quantity of carbonic acid or bicarbonates as to impair the action of the soda. Sufficient soda is used to break down the sulphates of lime and magnesia and as much lime added as is required to absorb the carbonic acid not taken up in the soda reaction.



PORTION OF 14,000 HORSE-POWER INSTALLATION OF STIRLING BOILERS AT THE LAKE SHORE STATION OF THE CLEVELAND ELECTRIC ILLUMINATING COMPANY, CLEVELAND, OHIO, WHICH HAS BOUGHT A TOTAL OF 67,400 HORSE POWER OF STIRLING BOILERS

All of the apparatus for effecting such treatment of feed waters is approximately the same in its chemical action, the numerous systems differing in the methods of introduction and handling of the reagents.

The methods of testing water treated by an apparatus of this description follow:

There is considerable difference of opinion as to the correct ratio of alkalinity, hardness and causticity in properly treated water. According to some authorities, the causticity should be from two to three times the hardness, and the alkalinity from one and a half to two times the causticity. If too little lime is used, the causticity will be too low, the hardness and alkalinity too high, and scale will result. If too much is used, the causticity will be too high. Where insufficient soda ash is used, the hardness is too high and alkalinity too low, and scale is also formed. Where too great a quantity of soda ash is used, priming and other troubles result.

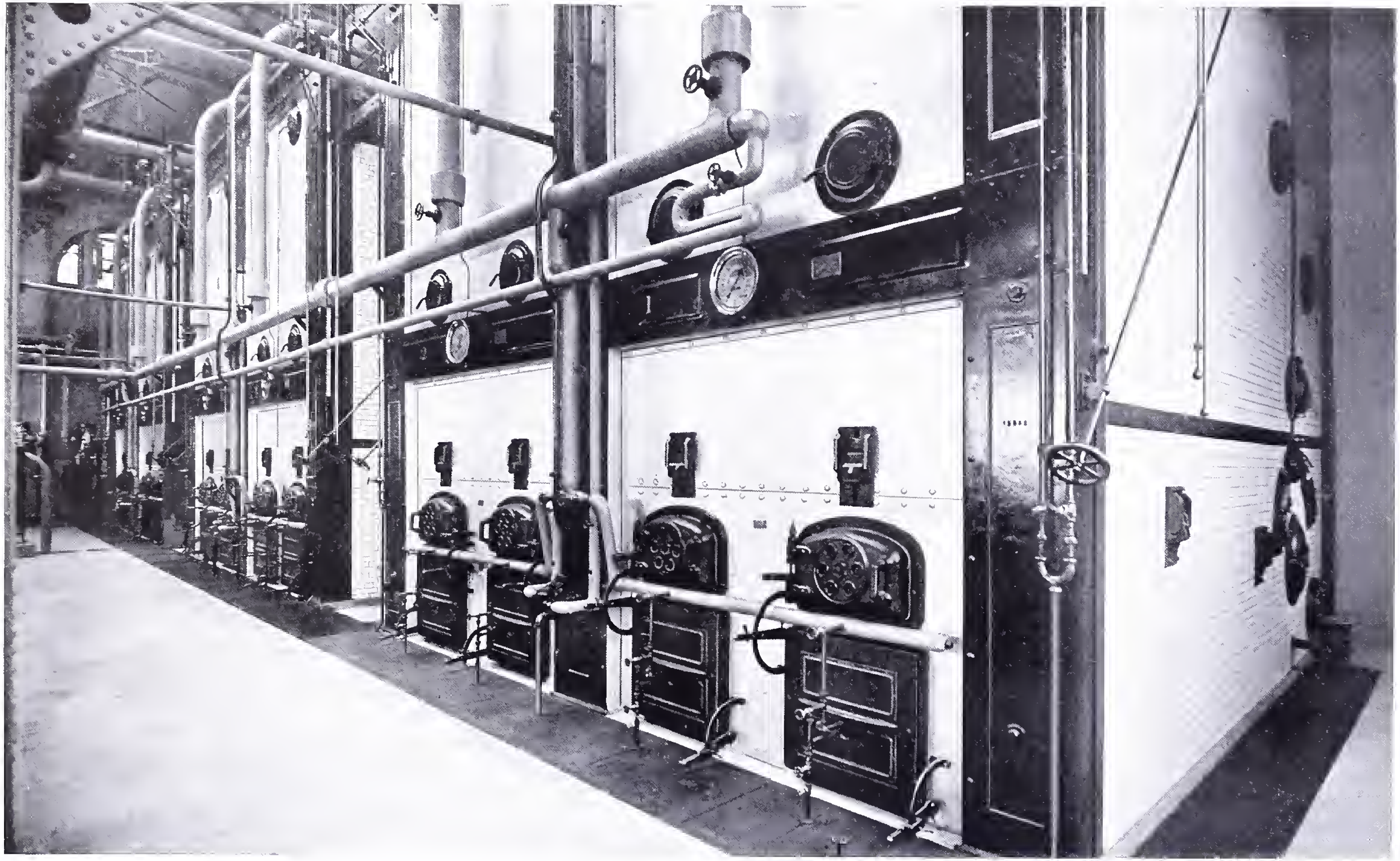
Alkalinity and causticity are tested with a standard solution of sulphuric acid. A standard soap solution is used for testing for hardness and a silver nitrate solution may also be used for determining whether an excess of lime has been used in the treatment.

Alkalinity: To 100 cubic centimeters of treated water, to which there has been added sufficient methylorange to color it, add the standard 10th normal acid solution, drop by drop, until the mixture is on the point of turning permanent red. As the standard 10th normal acid solution is first added, the red color, which shows quickly, disappears on shaking the mixture, and this color disappears more slowly as the critical point is approached. Number of cubic centimeters of the standard 10th normal acid solution used, multiplied by 50, equals parts per million of alkalinity as calcium carbonate.

Causticity: To 100 cubic centimeters of treated water, to which there has been added one drop of phenolphthalein dissolved in alcohol to give the water a pinkish color, add the standard 10th normal acid solution, drop by drop, shaking after each addition, until the color entirely disappears. Number of cubic centimeters of the standard 10th normal acid solution used, multiplied by 50, equals parts per million of causticity as calcium carbonate.

The alkalinity may be determined from the same sample tested for causticity by coloring it with methylorange and adding the acid until the sample is on the point of turning red. The total acid added in determining both causticity and alkalinity in this case is the measure of the alkalinity.

Hardness: 50 cubic centimeters of the treated water is used for this test. Number of cubic centimeters of the soap solution used, less seven-tenths of a cubic centimeter, multiplied by 14, equals the hardness in parts per million of calcium carbonate. The soap solution is added a very little at a time and the whole violently shaken. Enough of the solution must be added to make a permanent lather or foam, that is, the soap bubbles must not disappear after the shaking is stopped.



DEPARTMENT OF PUBLIC WORKS, PUMPING STATION No. 2 (FIRE PROTECTION SYSTEM), SAN FRANCISCO, CAL., OPERATING 2796 HORSE POWER OF STIRLING BOILERS

Excess of Lime as Determined by Nitrate of Silver: If there is an excess of lime used in the treatment, a sample will become a dark brown by the addition of a small quantity of silver nitrate, otherwise a milky white solution will be formed.

Combined Heat and Chemical Treatment: Heat is used in many systems of feed treatment apparatus as an adjunct to the chemical process. Heat alone will remove temporary hardness by the precipitation of carbonates of lime and magnesia and, when used in connection with the chemical process, leaves only the permanent hardness or the sulphates of lime to be taken care of by chemical treatment.

The chemicals used in the ordinary lime and soda process of feed water treatment are common lime and soda. The efficiency of such apparatus will depend wholly upon the amount and character of the impurities in the water to be treated. Table 3 gives the amount of lime and soda required per 1000 gallons for each grain per gallon of the various impurities found in the water. This table is based on lime containing 90 per cent calcium oxide and soda containing 58 per cent sodium oxide, which correspond to the commercial quality ordinarily purchasable. From this table and the cost of the lime and soda, the cost of treating any water per 1000 gallons may be readily computed.

TABLE 3

REAGENTS REQUIRED IN LIME AND SODA PROCESS FOR TREATING 1000 U. S. GALLONS OF WATER PER GRAIN PER GALLON OF CONTAINED IMPURITIES*

	Lime† Pounds	Soda‡ Pounds		Lime† Pounds	Soda‡ Pounds
Calcium Carbonate . . .	0.098	. . .	Ferrous Carbonate . . .	0.169	. . .
Calcium Sulphate	. . .	0.124	Ferrous Sulphate . . .	0.070	0.110
Calcium Chloride	. . .	0.151	Ferric Sulphate	0.074	0.126
Calcium Nitrate	. . .	0.104	Aluminum Sulphate . .	0.087	0.147
Magnesium Carbonate . .	0.234	. . .	Free Sulphuric Acid . .	0.100	0.171
Magnesium Sulphate . .	0.079	0.141	Sodium Carbonate . . .	0.093	. . .
Magnesium Chloride . .	0.103	0.177	Free Carbon Dioxide . .	0.223	. . .
Magnesium Nitrate . . .	0.067	0.115	Hydrogen Sulphate . .	0.288	. . .

*L. M. Booth Company.

†Based on lime containing 90 per cent calcium oxide.

‡Based on soda containing 58 per cent sodium oxide.

4th. *Zeolite Process*—Zeolite is a hydrated sodium aluminum silicate, and when water, containing calcium or magnesium, is passed through a bed of this material an exchange takes place whereby the sodium of the zeolite goes into solution and calcium and magnesium are removed. By a regenerative process with common salt the sodium is replaced in the zeolite.

Whenever waters high in calcium or magnesium carbonate or bicarbonate are treated by the zeolite process the treated water carries an equivalent amount

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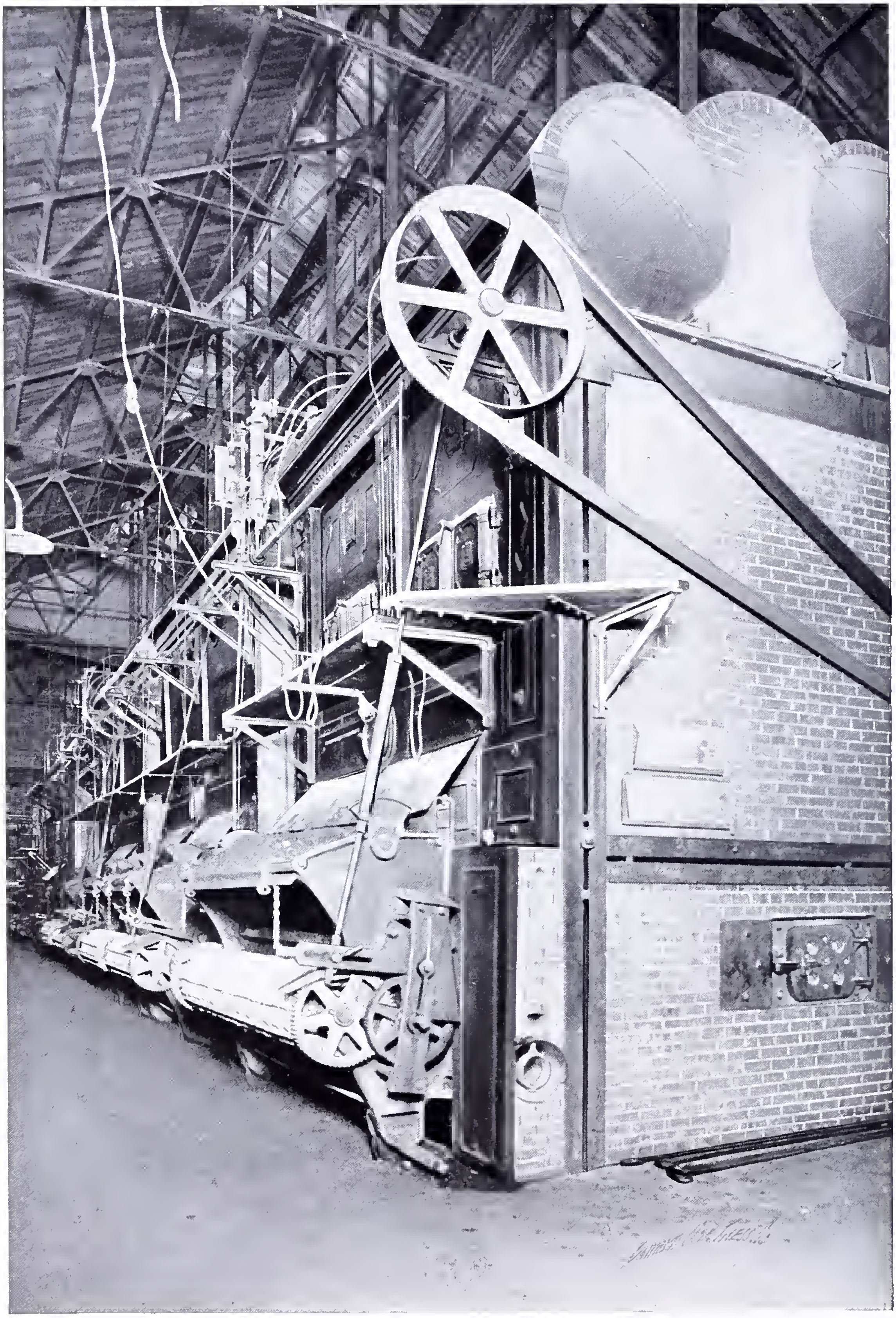


2800 HORSE-POWER INSTALLATION OF STIRLING BOILERS FOR THE LA SALLE PLANT OF THE ALPHA PORTLAND CEMENT COMPANY, WHICH OWNS A TOTAL OF 5900 HORSE POWER OF STIRLING BOILERS

of sodium carbonate or bicarbonate. Such waters when concentrated in the boiler cause priming and are, apparently, chemically the same as certain waters that have frequently caused embrittlement of the boiler plates. Highly carbonated waters can be treated by the following process.

5th. *Lime Zeolite Process*—This process embodies the principles of the first and fourth processes just described. By treating with lime the carbonates are removed and then the zeolite process is used to remove the permanent hardness. Priming dangers are materially reduced and the embrittling danger is removed.

LESS USUAL REAGENTS—Barium hydrate is sometimes used to reduce permanent hardness or the calcium sulphate component. Until recently, the high cost of barium hydrate has rendered its use prohibitive but at present it is obtained as a by-product in cement manufacture and it may be purchased at a more reasonable figure than heretofore. It acts directly on the soluble sulphates to form barium sulphate which is insoluble and may be precipitated. Where this reagent is used, it is desirable that the reaction be allowed to take place outside of the boiler, though there are certain cases where its internal use is permissible.

Barium carbonate is sometimes used in removing calcium sulphate, the products of the reaction being barium sulphate and calcium carbonate, both of which are insoluble and may be precipitated. As barium carbonate in itself is insoluble, it cannot be added to water as a solution and its use should, therefore, be confined to treatment outside of the boiler.

Silicate of soda will precipitate calcium carbonate with the formation of a gelatinous silicate of lime and carbonate of soda. If calcium sulphate is also present, carbonate of soda is formed in the above reaction, which in turn will break down the sulphate.

Oxalate of soda is an expensive but efficient reagent which forms a precipitate of calcium oxalate of a particularly insoluble nature.

Alum and iron alum will act as efficient coagulants where organic matter is present in the water. Iron alum has not only this property but also that of reducing oil discharged from surface condensers to a condition in which it may be readily removed by filtration.

CORROSION—Where there is a corrosive action because of the presence of acid in the water or of oil containing fatty acids, which will decompose and cause pitting wherever the sludge can find a resting place, it may be overcome by the neutralization of the water by carbonate of soda. Such neutralization should be carried to the point where the water will just turn red litmus paper blue. As a preventive of such action arising from the presence of the oil, only the highest grades of hydrocarbon oils should be used.

Acidity will occur where sea water is present in a boiler. There is a possibility of such an occurrence in marine practice and in stationary plants using sea water for condensing, due to leaky condenser tubes, priming in the evaporators, etc. Such acidity is caused through the dissociation of magnesium chloride into

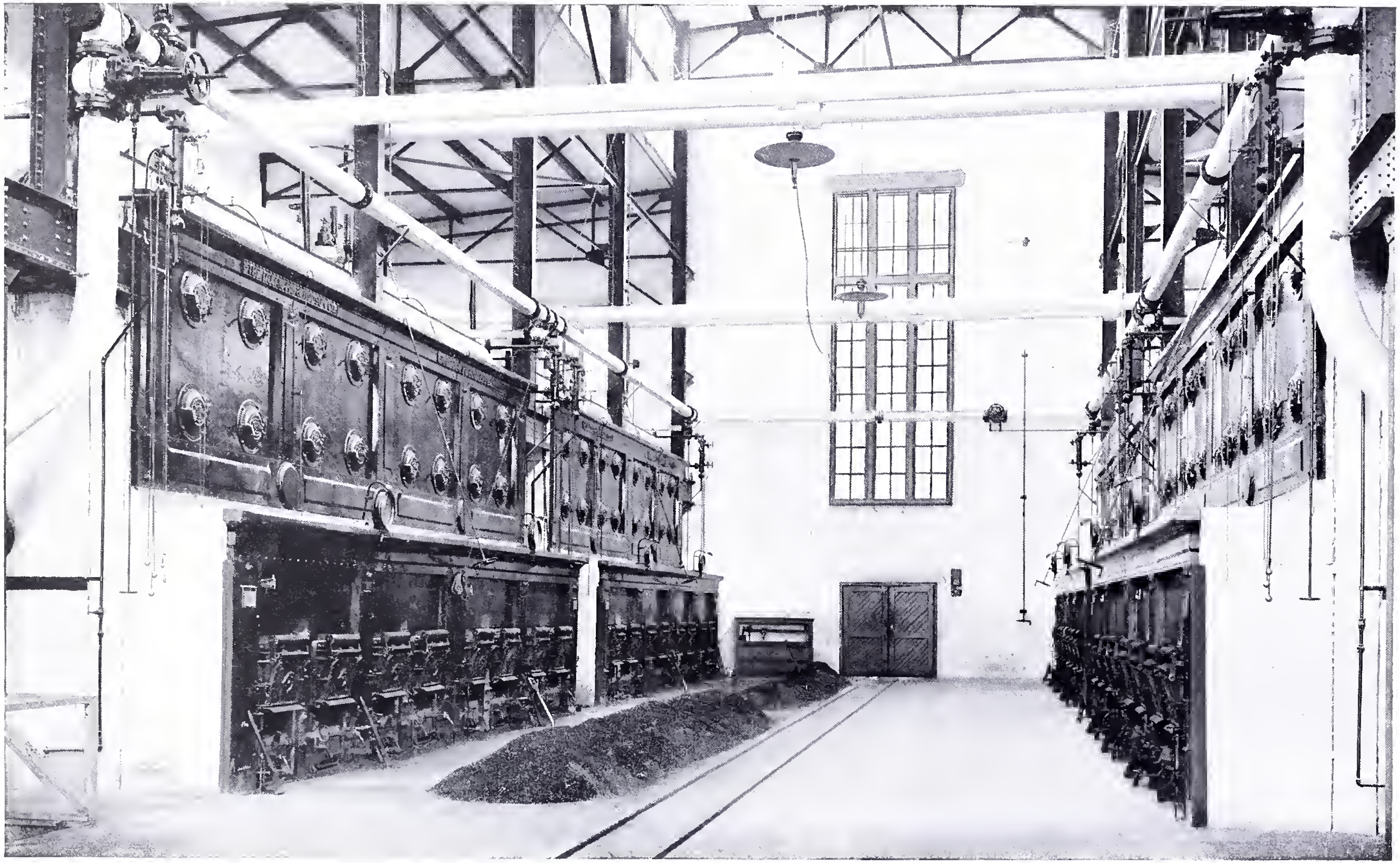
1800 HORSE-POWER INSTALLATION OF STIRLING BOILERS FOR THE BROWN & SHARPE MANUFACTURING COMPANY
PROVIDENCE, R. I.

hydrochloric acid and magnesia under high temperatures. The acid in contact with the metal forms an iron salt which immediately upon its formation is neutralized by the free magnesia in the water, thereby precipitating iron oxide and reforming magnesium chloride. The preventive for corrosion arising from such acidity is the keeping tight of the condenser. Where it is unavoidable that some sea water should find its way into a boiler, the acidity resulting should be neutralized by soda ash. This will convert the magnesium chloride into magnesium carbonate and sodium chloride, neither of which is corrosive but both of which are scale-forming.

The presence of air in the feed water which is sucked in by the feed pump is a well recognized cause of corrosion. Air bubbles form below the water line and attack the metal of the boiler, the oxygen of the air causing oxidization of the boiler metal and the formation of rust. The particle of rust thus formed is swept away by the circulation or is dislodged by expansion and the minute pit thus left forms an ideal resting place for other air bubbles and the continuation of the oxidization process. The prevention is, of course, the removing of the air from the feed water. In marine practice, where there has been experienced the most difficulty from this source, it has been found to be advantageous to pump the water from the hot well to a filter tank placed above the feed pump suction valves. In this way the air is liberated from the surface of the tank and a head is assured for the suction end of the pump. In this same class of work, the corrosive action of air is reduced by introducing the feed through a spray nozzle into the steam space above the water line.

Galvanic action, resulting in the eating away of the boiler metal through electrolysis was formerly considered practically the sole cause of corrosion. But little is known of such action aside from the fact that it does take place in certain instances. The means adopted as a remedy is usually the installation of zinc plates within the boiler, which must have positive metallic contact with the boiler metal. In this way, local electrolytic effects are overcome by a still greater electrolytic action at the expense of the more positive zinc. The positive contact necessary is difficult to maintain and it is questionable just what efficacy such plates have except for a short period after their installation when the contact is known to be positive. Aside from protection from such electrolytic action, however, the zinc plates have a distinct use where there is the liability of air in the feed, as they offer a substance much more readily oxidized by such air than the metal of the boiler.

Foaming—Where foaming is caused by organic matter in suspension, it may be largely overcome by filtration or by the use of a coagulant in connection with filtration, the latter combination having come recently into considerable favor. Alum, or potash alum, and iron alum, which in reality contains no alumina and should rather be called potassia-ferric, are the coagulants generally used in connection with filtration. Such matter as is not removed by filtration may, under certain conditions, be handled by surface blowing. In some instances, settling



AN INSTALLATION OF STIRLING BOILERS AT THE MECHANICSVILLE, N. Y., PLANT OF THE DELAWARE AND HUDSON COMPANY, WHICH HAS BOUGHT 33,700 HORSE POWER OF THESE BOILERS

tanks are used for the removal of matter in suspension, but where large quantities of water are required, filtration is ordinarily substituted on account of the time element and the large area necessary in settling tanks.

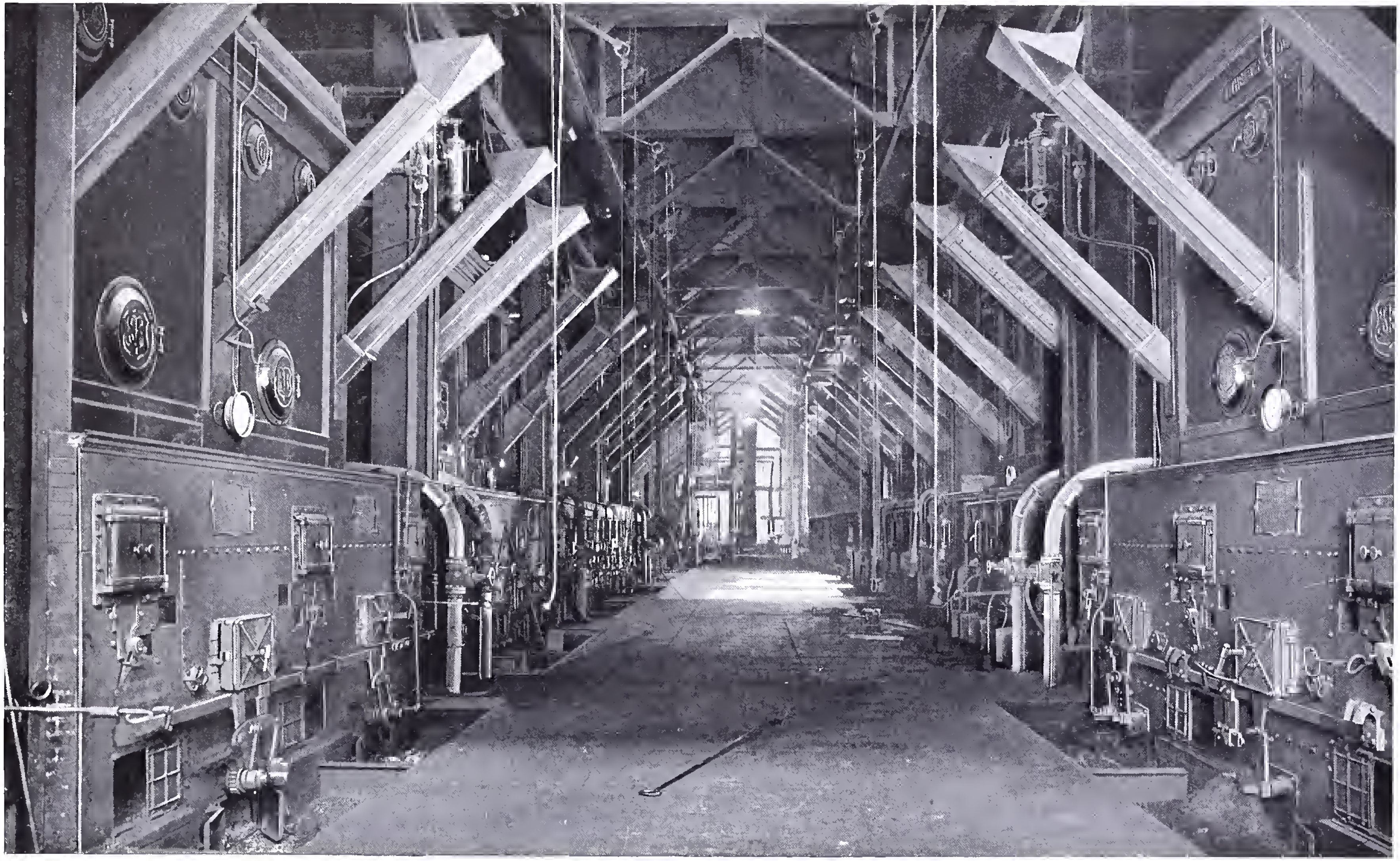
Where foaming occurs as the result of overtreatment of the feed water, the obvious remedy is a change in such treatment.

PRIMING—Where priming is caused by excessive concentration of salts within a boiler, it may be overcome largely by frequent blowing down. The degree of concentration allowable before priming will take place varies widely with conditions of operation and may be definitely determined only by experience with each individual set of conditions. It is the presence of the salts that cause priming that may result in the absolute unfitness of water for boiler feed purposes. Where these salts exist in such quantities that the amount of blowing down necessary to keep the degree of concentration below the priming point results in excessive losses, the only remedy is the securing of another supply of feed, and the results will warrant the change almost regardless of the expense. In some few instances, the impurities may be taken care of by some method of water treatment but such water should be submitted to an authority on the subject before any treatment apparatus is installed.

BOILER COMPOUNDS—The method of treatment of feed water by far the most generally used is by the use of some of the so-called boiler compounds. There are many reliable concerns handling such compounds who unquestionably secure the promised results, but there is a great tendency toward looking on the compound as a "cure all" for any water difficulties and care should be taken to deal only with reputable concerns.

The composition of these compounds is almost invariably based on soda with certain tannic substances and in some instances a gelatinous substance which is presumed to encircle scale particles and prevent their adhering to the boiler surfaces. The action of these compounds is ordinarily to reduce the calcium sulphate in the water by means of carbonate of soda and to precipitate it as a muddy form of calcium carbonate which may be blown off. The tannic compounds are used in connection with the soda with the idea of introducing organic matter into any scale already formed. When it has penetrated to the boiler metal, decomposition of the scale sets in, causing a disruptive effect which breaks the scale from the metal sometimes in large slabs. It is this effect of boiler compounds that is to be most carefully guarded against or inevitable trouble will result from the presence of loose scale with the consequent danger of tube losses through burning.

When proper care is taken to suit the compound to the water in use, the results secured are fairly effective. In general, however, the use of compounds may only be recommended for the prevention of scale rather than with the view to removing scale which has already formed, that is, the compounds should be introduced with the feed water only when the boiler has been thoroughly cleaned.



A PORTION OF THE 21,700 HORSE POWER OF STIRLING BOILERS BOUGHT BY THE B. F. GOODRICH RUBBER COMPANY, AKRON, OHIO

STOKER-FIRED FURNACE BRICKWORK

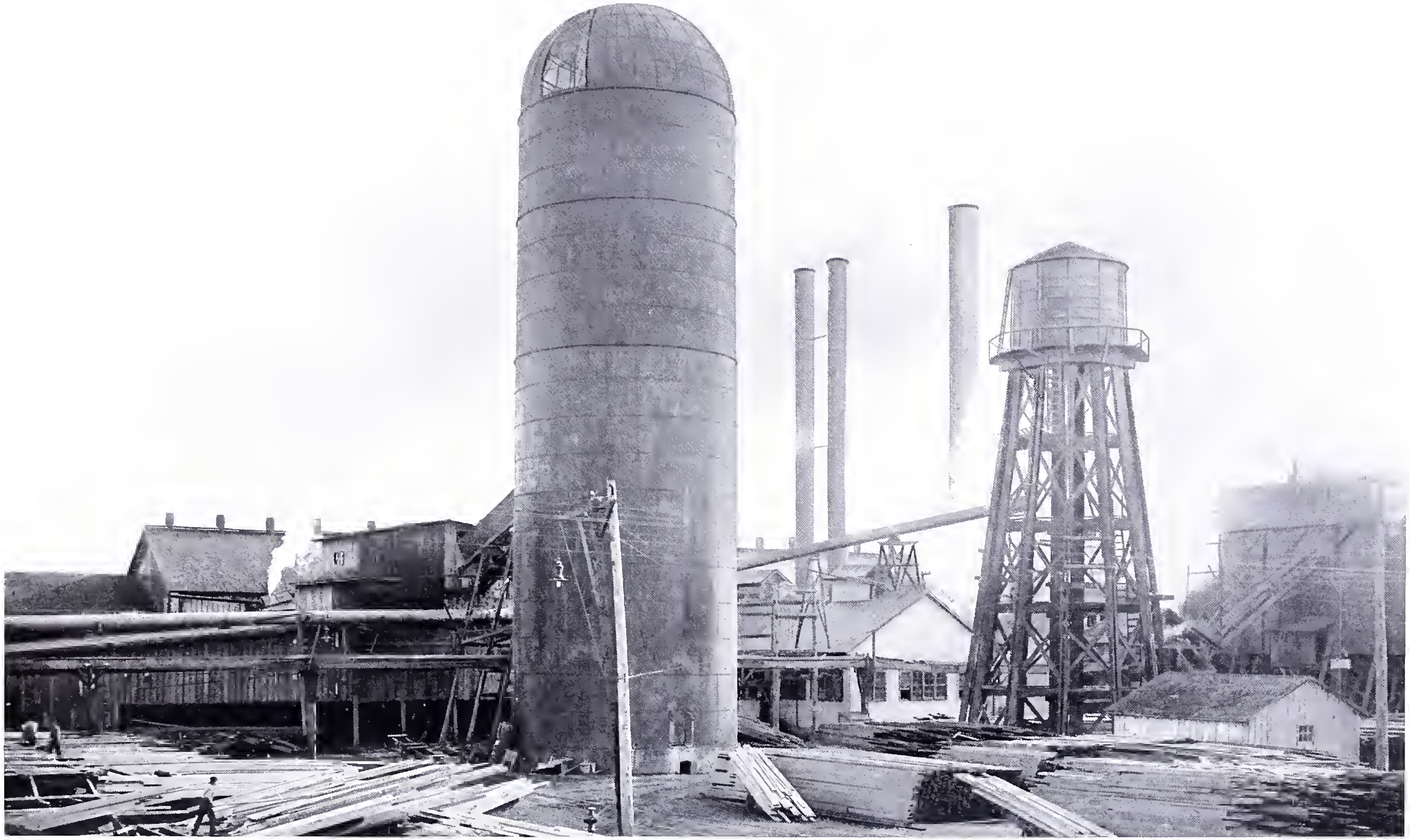
THE consideration of brickwork for stoker-fired furnaces may be divided into three parts, namely: furnace design, quality of brick used, and workmanship in the laying up of brick. The question as here considered is limited to the furnace proper, and deals, therefore, only with fire brick.

Design—The design of the furnace is obviously of the greatest importance. Such design, however, varies so widely with different types of boilers and stokers, different fuels, and different operating conditions that no general statement that will apply to all cases may be made as to what constitutes a proper furnace design. The number of possible combinations of boilers, stokers, fuels and operating conditions is so very large that no attempt will be made here to suggest a furnace design. Each individual installation of boiler and stoker should be considered by itself and the furnace design based upon experience as to what has given the most satisfactory service for a similar set of conditions.

Quality of Fire Brick—The modern tendency toward high overloads has increased greatly the severity of the service under which furnace brickwork is called upon to stand, and to a very great extent the life of the furnace is dependent upon the quality of fire brick entering into its construction.

Excluding the workmanship in building a furnace, and considering only the quality of the fire brick itself, failures in service can be traced to a small number of comparatively simple reasons. These reasons are given approximately in the order of their relative importance, the most important first:

Plastic Deformation—When a brick is subjected to successively higher temperatures, it ordinarily changes shape by expansion. As the temperature increases, there may be a period in which shrinkage is taking place, and at some temperature plastic deformation occurs, even under no greater load than its own weight. Expansion and shrinkage are to be distinguished from plastic deformation, because the two former leave the brick geometrically similar to its original shape, while the latter does not, and is the result of an externally applied stress, such as gravity. Fire-clay brick of the best quality generally obtainable begin to show plastic deformation under a load of 20 pounds per square inch at from 2200 to 2400 degrees Fahrenheit. Reduction in the load to 10 pounds per square inch will increase this limit about 200 degrees Fahrenheit. The importance of this quality in fire-clay brick in boiler furnaces appears when it is recognized that furnace temperatures as high as 2400 degrees Fahrenheit are frequent in hand-firing with coal, and may reach 2700 degrees Fahrenheit with stokers and 3000 degrees Fahrenheit with oil. It is evident, since the load due to the design of the furnace may be as high as 15 pounds per square inch, that should the temperature of the brickwork reach the furnace temperature for any considerable depth in



ANDERSON & MIDDLETON LUMBER COMPANY, ABERDEEN, WASH., OPERATING 2000 HORSE-POWER STIRLING BOILERS

the brickwork, fire-clay brick could not be used at all for boiler furnaces. These figures also show the necessity for protecting furnace arches from full furnace temperatures on both sides of the arch and for avoidance of pressures in the furnace above atmosphere.

A method of testing brick for this characteristic is given in the Technologic Paper No. 7 of the Bureau of Standards dealing with "The Testing of Clay Refractories, with Special Reference to Their Load Carrying Capacity at Furnace Temperatures." Referring to the test for this specific characteristic, this publication recommends the following: "When subjected to the load test in a manner substantially as described in this bulletin, at 1350 degrees centigrade (2462 degrees Fahrenheit), and under a load of 50 pounds per square inch, a standard fire brick tested on end should show no serious deformation and should not be compressed more than 1 inch, referred to the standard length of 9 inches."

Activity—Under this general word may be grouped the causes of failure resulting from expansion and shrinkage. If expansion or shrinkage occurs slowly (that is to say, if for a given percentage of volume change a considerable temperature range is required and the rate of change is more or less continuous), then the failure of the brick structure comes about from dislocation of the furnace structure as a whole; that is, the results are evident in bulging and cracking of walls. Expansion of this sort may occur every time the brick passes through a large range of temperature, the brick returning about to its original volume when the temperature returns to its starting point. Unfortunately, the brick structure under such action does not return to its original shape. Shrinkage of the slow and continuous type referred to is more apt to be permanent, and on this account is not apt to recur each time the brick passes through a cycle of temperature change. For this reason, if a brick structure does not have trouble from shrinkage the first time it is brought up to its working temperature and back again, it is not likely that trouble from this cause will ever be experienced.

Where expansion or shrinkage occurs within a very narrow temperature range, if the change of volume is also considerable, then disintegration of the brick by "spalling" is apt to occur. The reason for spalling under these conditions is double, since a sudden volume change within a close temperature range usually corresponds to a marked change in the chemical structure of the brick, and since, also, the effect of the temperature gradient through the brick becomes greater. Various tests for determining this quality of brick are used. They are all relative tests, as distinct from measurements. One test consists in heating the brick to some standard temperature, as, for example, 2500 degrees Fahrenheit, and quenching it in water or an air or steam blast. Another consists in heating one face of the brick so rapidly that the brick for a small depth below the face is at a temperature of 2400 to 3000 degrees Fahrenheit when the remainder of the brick is comparatively cold. Any test of this sort yields information from which the spalling quality of a brick in service can be predicted with a good deal of certainty

PORTION OF 19,000 HORSE-POWER INSTALLATION OF STIRLING BOILERS FOR THE PITTSBURGH STEEL COMPANY
MONESSON, PA.

if a sufficient number of various other sorts of brick have undergone the test and if sufficient is known from actual experience as to how they perform in service.

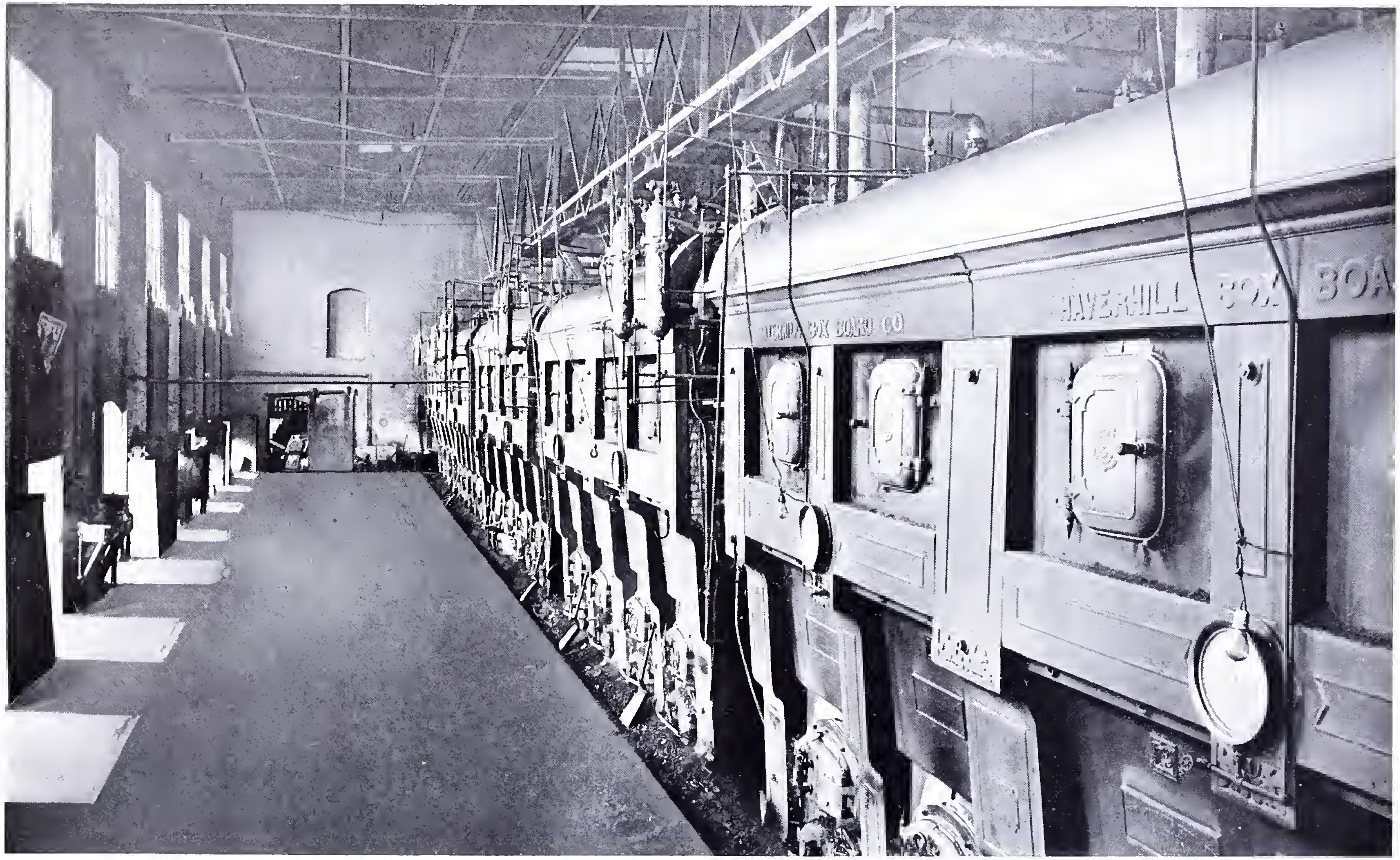
Tests for expansion and shrinkage lend themselves to measurements with a fair degree of convenience, and a limit for first-class fire-clay brick of 1 per cent linear at 3000 degrees Fahrenheit for the best quality of fire-clay brick for boilers should not be exceeded. A corresponding limit for shrinkage is also satisfactory.

Fusion Point—Under ordinary furnace operating conditions in boilers, the interior surface of the brick will approach quite closely the temperature of the furnace (flame temperature), so that fire brick to be satisfactory in this respect should have a fusion point above the flame temperature of the furnace by a distinct margin, probably not less than 100 degrees Fahrenheit and preferably 200 degrees Fahrenheit. At first sight, the fusion point of a fire brick would appear to be its most important characteristic, but in practice, failure in a brick structure will ordinarily take place from plastic deformation before failure by fusion appears. At small areas in a furnace, failure from fusion may take place without the furnace as a whole showing evidence of deformation, but such a difficulty is usually controllable by design. First-class fire-clay brick should show a fusion point above 3100 degrees Fahrenheit.

Slagging—Failure from the effect of slagging is ordinarily met with in the region of the fuel bed, but can occur under furnace conditions where particles of molten slag are brought by the gases into contact with the brickwork. The resistance of a given brick to slagging is the result of its chemical composition, and its physical structure as well. Fire-clay bricks, as a class, chemically, are reasonably resistant to slags such as are ordinarily formed in boiler furnaces from the usual varieties of coal. They are by no means as resistant as kaolin brick, though difficulties in the manufacture of kaolin brick have prevented as yet their coming into general use. The variation in the amount of trouble experienced with various fire-clay brick from slagging is to be explained chiefly by their macro-structure, which, in turn, is influenced by the sieve characteristics of the flint clay, the nature of the bond and similar details of manufacture. There is no exact measurement test for this characteristic of a brick, the test ordinarily used being either that given in the American Society for Testing Materials Specification No. C20 or one of a very similar character.

A fire-clay brick for boiler furnaces may safely be said to be of the best quality generally obtainable for the purpose if it meets the limiting figures given above for plastic deformation, fusion, expansion and shrinkage, and if its action under the spalling test classifies it with other fire-clay brick that experience has shown work well in practice in that particular.

Nothing has been so far said as to the information that chemical analysis, density and porosity measurements, hardness, flint-clay nodule size, color, etc., may reveal. The reason for the omission of these characteristics of the fire-clay



1960 HORSE-POWER INSTALLATION OF STIRLING BOILERS FOR THE HAVERHILL BOX BOARD COMPANY
HAVERHILL, MASS.

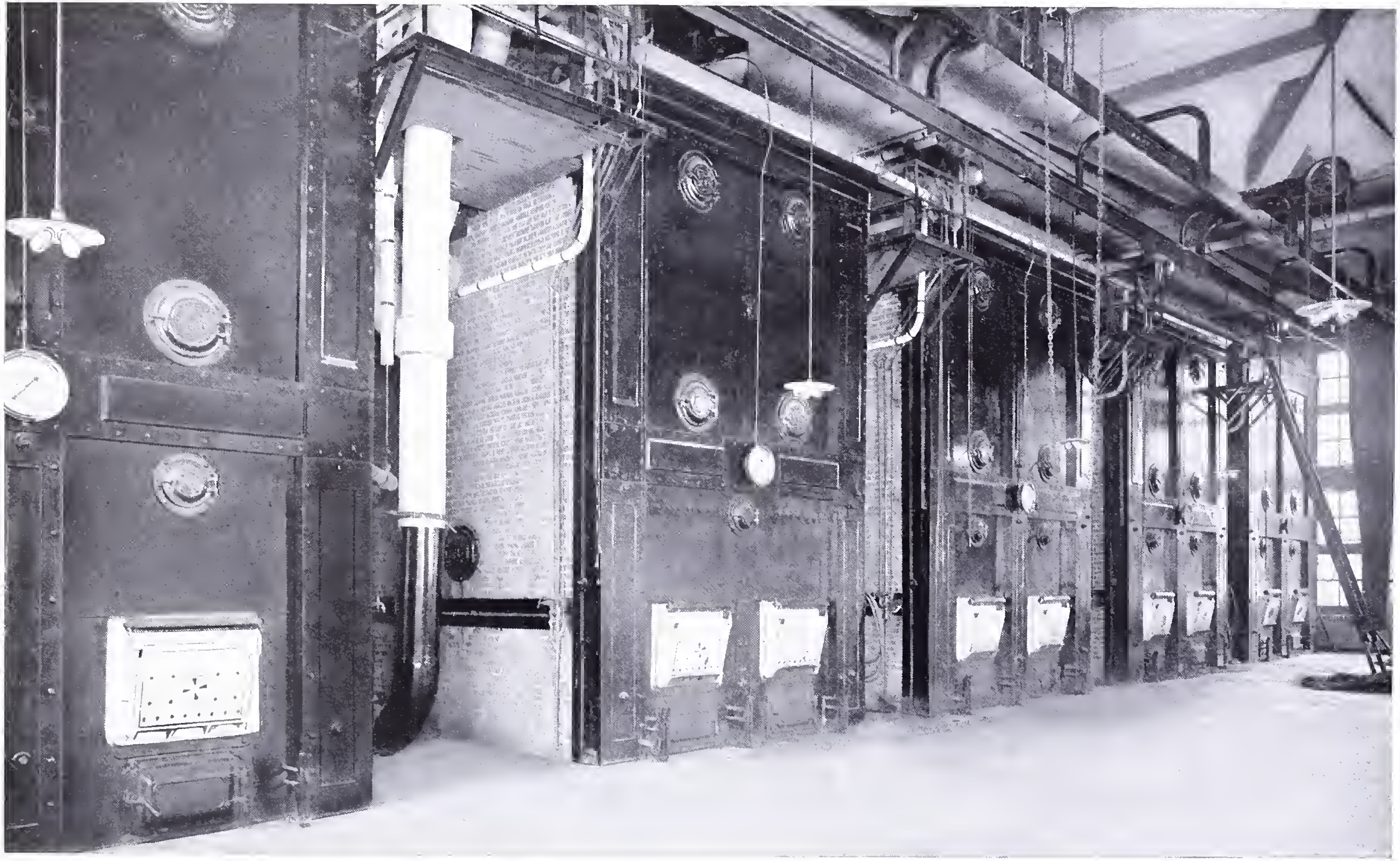
brick for boiler service from the causes of failure of such brick is that, though they are all of effect in failures, they are either difficult to determine or misleading in the information that they give. Proper chemical composition will not insure good brick, and the opposite is true within limits, that is, a brick that is not of specially good chemistry may, by proper sizing, bonding, burning and other manufacturing methods, actually give better results in practice than a less well-made brick of better chemistry. In general, fire-clay brick found to be especially good for high-temperature conditions will be found in the middle range of hardness, rather above the average in porosity and below it in density, and the brick will be, when fractured, rough in texture, with the flint-clay nodule areas prominent. The color of the fracture will be from yellow toward white, with absence of red, the latter being indicative of iron. It is to be borne in mind that a given amount of iron will show color principally in proportion to its dispersion, so that any judgment as to the amount of iron present from the reddish color of the brick is extremely uncertain.

Fire Clay and Mortar—The fire clay or "cement" used in laying up fire brick affects the life of the structure to a very serious extent. If ordinary fire clays are used, it is a good rule that fire clay should be chemically as like the brick as possible, and finely ground. If a "cement" is used, its point of fusion should be as high as the fusion point of the brick, and its initial point of vitrification (which, roughly speaking, is the point at which its cementing action comes into play) should be low, in order that its holding power can be developed through as much of the brickwork structure as possible. It should also have, as in the case of fire clay, chemical similarity to the fire brick, or at least should be such as will not strongly react with it. The life of a brickwork structure built with a given kind of brick can undoubtedly be increased by the use of the best "cement" now on the market, as against ordinary fire clays, for such cements may have a fusion point higher than that of the brick, and if correct from the point of view of vitrification, will tend to prevent leaching of the gases between the brick, and will, on that account, tend to keep the mean temperature of the brick at a minimum.

While the available cements are, to the extent indicated, binders, ordinary fire clay is in no sense a binder. The sole function of fire clay and the principal function of cement is the filling of the irregularities or voids in the brick and the prevention of the leaching of the hot gases into the brick wall.

The shrinkage of fire clays is appreciable and it is for this reason that, as pointed out hereafter, it must be used in small quantities.

Laying Up—With the grade of brick and fire clay or "cement" selected best suited to the service of the boiler to be set, the other factor affecting the life of the boiler setting is the laying. While it is probable that more setting difficulties arise from improper workmanship in the laying up of the brick than from poor material, on the other hand no written instructions, specifications or description of the methods to be followed in this work will compensate for



1900 HORSE-POWER INSTALLATION OF STIRLING BOILERS FOR THE CURTIS PUBLISHING COMPANY, PHILADELPHIA, PA.
FRANK C. ROBERTS & CO., ENGINEERS. THIS PUBLISHER HAS BOUGHT 3300 HORSE POWER OF STIRLING BOILERS

the lack of an elementary knowledge of good and poor brick and proper and improper joints.

Unfortunately, fire brick and even red brick in any local district are not of the same sizes. This makes it difficult if not impossible to tie fire brick into red brick backing unless special provision is made to insure that the brick are of the correct size. If the red brick that is used in backing a fire-brick wall is of the correct size, all joints will be broken uniformly throughout the wall, all joints can be made of a minimum thickness, and both inside and outside faces of the wall can be left a true plane.

It is not expected, in backing a fire-brick wall with red brick, that the joints can be held as thin or as uniform in the red-brick backing as in the fire-brick lining. It is, however, recognized that, if proper care is used in the selection of the brick and the workmanship in laying up, the joints of the red-brick backing can be held down to a thickness that will not affect the stability of the structure or the life of the wall. No joints in a red-brick wall should exceed $\frac{5}{16}$ inch.

Fire brick, when laid for any purpose, should always be dipped in thin fire clay or "cement," and under no circumstance should be "buttered." As each course of the wall is laid, it should be grouted with very thin fire clay, and after the grouting has been brushed into the joints and all joints filled, the surplus should be entirely removed from the top of that course.

In the red-brick backing, the same method of laying up should be followed, the only difference being that the red brick should be spread to a thickness that will hold the upper face of the red-brick course in the same plane as the corresponding course of fire brick, and that a lime and cement grout should be used to slush the red brick instead of fire clay.

The pointing up of joints in any brick wall is solely to give the finished appearance of a new job. The boiler wall should be so laid up that the pointing up is reduced to only the smoothing of the visible joints, and should not be a filling of any joints that should have been filled from the inside during the laying of any course.

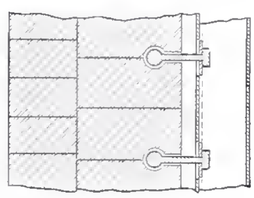
All 4½-inch fire-brick walls should be four stretchers and one header. All fire-brick linings 9 inches or over should be laid up of four courses of headers and one stretcher backed with a header of fire brick. Furnace center-walls should be built entirely of fire brick. If the center of such walls is built of red brick, they will often melt down and cause the failure of the wall as a whole.

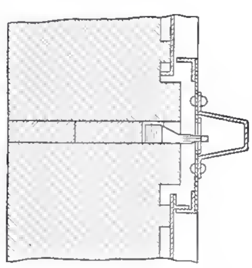
Fire-brick arches should be constructed of selected brick which are smooth, straight and uniform. The forms on which such arches are built, called arch centers, should be constructed of batten strips not over 2 inches wide. The brick should be laid on these in courses, not in rings, each joint being broken with a bond equal to the length of half a brick. Each course should be tried in place dry and should be checked with a straight edge to insure all the brick of one course being the same thickness. Each brick should be dipped on one side and one edge only and tapped into place with a mallet. Wedge brick courses should be

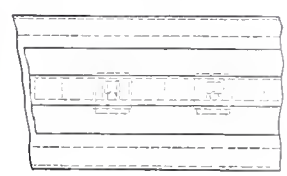
HARWOOD ELECTRIC POWER CO., HARWOOD, PA., OPERATING 10,400 HORSE POWER OF STIRLING BOILERS

used only where necessary to keep the bottom faces of the straight brick course in even contact with the centers. When such contact cannot be exactly secured by the use of wedge brick, the straight brick should lean away from the center of the arch rather than toward it. When the arch is approximately two-thirds completed, a trial ring should be laid to determine whether the key course will fit. When cutting is necessary to secure such a fit, it should be done on the two adjacent courses on the side of the brick away from the key. It is necessary that the keying course be a true fit from top to bottom, and after it has been dipped and driven it should not extend below the surface of the arch, but preferably should have its lower edge $\frac{1}{4}$ inch above this surface. After fitting, the keys should be dipped, replaced loosely, and the whole course driven uniformly into place by means of a heavy hammer and a piece of wood extending the full length of the keying course. Such a driving in of this course should raise the arch as a whole from the center. The center should be so constructed that it may be dropped free from the arch when the key course is in place and removed from the furnace without being burned out.

Bonding Tile—The walls of boiler furnaces subjected to high temperatures, and particularly with the larger furnace volumes and increased boiler capacities that are coming into general use, tend to bulge inward and, in some instances, fail by falling inward. A method that has been successfully employed for holding furnace walls in alignment is shown in the accompanying illustration. This construction, which is patented, consists of introducing horizontal rows of bonding tile in the walls, the tile being attached by members to horizontal buckstays outside the walls in such manner that the wall can expand freely both vertically and horizontally and is still given stability and prevented from bulging either inwardly or outwardly.



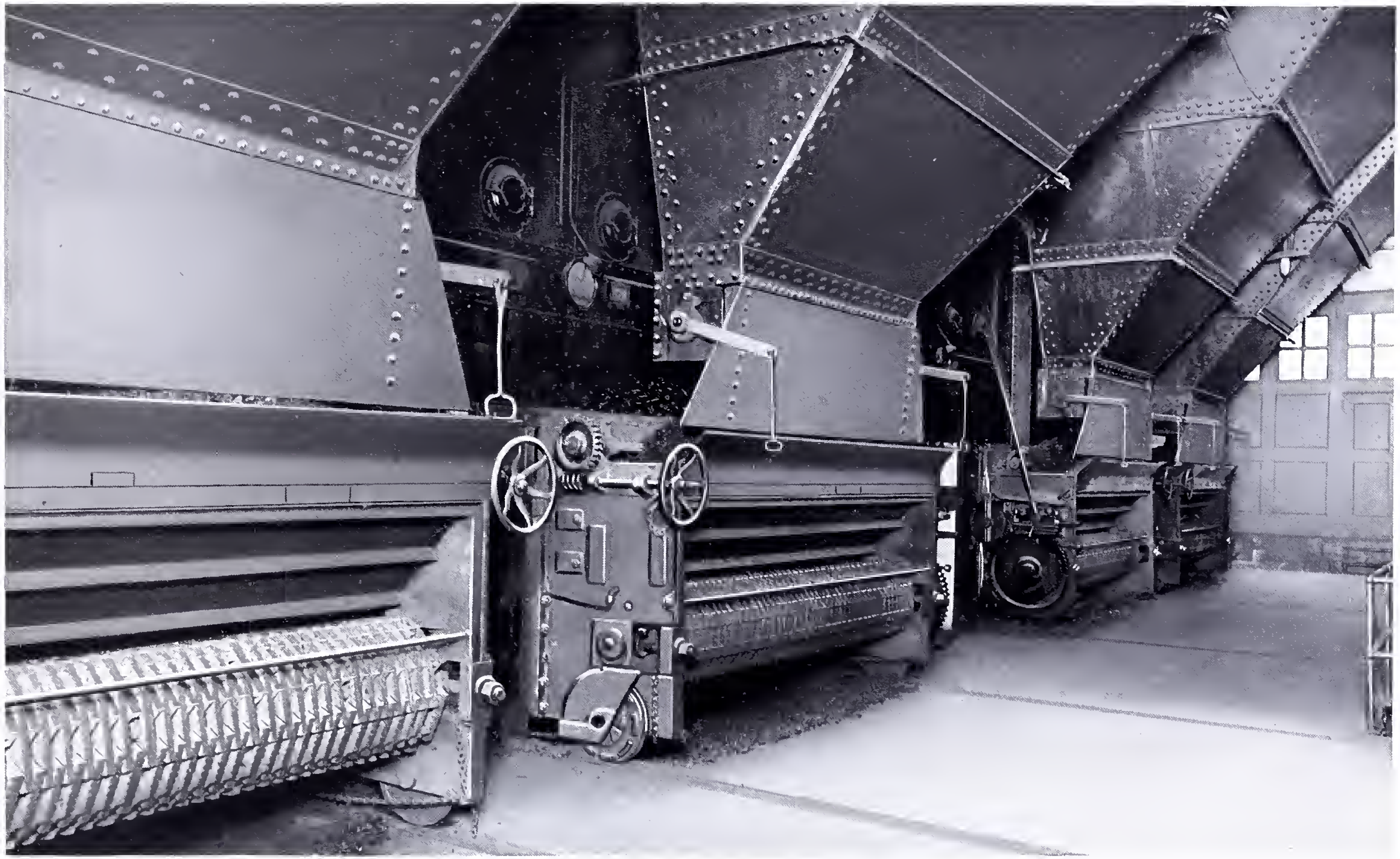




BONDING TILE

Relation of Draft to Setting Brickwork—The bearing that the draft available has upon the boiler setting and particularly the furnace setting is a factor that, in general, has only recently been given its proper consideration. Such a relation is to be distinguished from that of draft and combustion rates.

The draft available should be such as to provide a suction throughout all parts of the boiler setting at all times and under all conditions of operation. Where such a suction does not exist and a back pressure is found at any point in the setting, there is a tendency to force the gases of combustion outward through the boiler setting and to overheat the brickwork and access and inspection doors.



PUBLIC SERVICE CO., OF NORTHERN ILLINOIS, OAK PARK, ILL., STATION. BABCOCK & WILCOX CHAIN GRATE STOKERS INSTALLED WITH 2050 HORSE POWER OF STIRLING BOILERS

This overheating, which will increase as the gases are hotter or as the boiler furnace is approached, will naturally cause a rapid deterioration of the setting and warping of the doors and frames. Where the products of combustion are not carried away from the boiler furnace and through the setting by an ample draft suction, the cost of upkeep of the setting will be excessive and will be greatest where such a suction does not exist in the boiler furnace. Here the highest temperatures are found and, if the hot gases are not removed promptly, the "soaking up" of the heat by the furnace walls and arches cannot but be harmful from the standpoint of length of life.

With a natural-draft stoker, the fact that there is sufficient draft in the furnace to burn the necessary amount of coal to develop the rating at which the boiler is being operated is ordinarily a safe indication that there is a draft suction throughout all parts of the setting and that the gases are being properly carried away from the furnace. This statement, of course, refers to those instances in which there is no undue loss in draft in passing from the furnace proper to the point at which the gases encounter the boiler heating surface.

With forced-draft stokers, on the other hand, the blast is ordinarily relied upon to give the required combustion rates. With this class of apparatus, therefore, the function of the stack is simply to remove the products of combustion from the furnace and it is in such cases that the question of suction throughout *all* parts of the setting is to be watched.

It may be readily conceived and, in fact, the condition is frequently found in practice, that a draft suction in the boiler furnace does not necessarily indicate that such a suction exists throughout all parts of the setting. For instance, in a boiler with vertical or semi-vertical passes for the gases, a suction may be found in the furnace while at the top of such a pass a slight back pressure may exist. Such condition is due to the effect of the column of heated gases passing upward, which acts in the same way as the gases in a chimney, insofar as providing a draft at the bottom is concerned.

In determining stack sizes for forced-draft stokers, as for all boiler work, the diameter is a function of the amount of gases to be handled and should be made such as to give no undue frictional resistance to the gases because of insufficient area. The height is purely a function of the draft that must be supplied. With natural-draft stokers, as with hand firing, it must be sufficient to provide in the boiler furnace ample draft to give the combustion rate necessary to develop the maximum capacity at which the boiler is to be operated, proper attention being given to losses in draft due to length of flues, turns, resistance offered in the passage through the boiler, etc.

With forced-draft stokers the stack height must be such that a draft suction is assured throughout all portions of the setting under all conditions of operation, regardless of the intensity of the blast supplied to give the necessary combustion rates, and the same attention must be given to factors causing draft losses.

In the early days of forced-draft stoker work, manufacturers of this class of apparatus had a tendency to overcarry the mark so far as the reduction in stack sizes was concerned, taking a stand that their product required practically no stack. The importance of furnace and setting upkeep cost, however, is now appreciated by such manufacturers and they are insisting that sufficient stack be provided to maintain a draft suction throughout the boiler under all conditions.

TESTS OF STIRLING BOILERS WITH VARIOUS FUELS

Plant		Cincinnati W. W.	AmericanSheet & Tin Plate Co.	Gilman Paper Co.
Location		Cincinnati, O.	Vandergrift, Pa	Gilman, Vt.
Boiler heating surface	sq. ft.	4272*	6032	5210
Rated horse power	H. P.	427	600	521†
Type of furnace		Underfeed	Chain Grate	Underfeed
Grate surface	sq. ft.	84	126	65
Fuel		Bit. run of mine	Bit. slack	Bit. slack
Source or trade name		Pittsburgh	Upper Freeport	Pocahontas
Duration of test	hours	144	24	10
Steam pressure by gauge	lbs.	156.4	125.7	164.8
Temperature of feed water	°F.	211.6	79.8	204.3
Degree of superheat	°F.	. . . . .	111.3	64.7
Factor of evaporation		1.0469	1.2422	1.0949
Blast under grates	inches	1.70	. . . . .	4.38
Draft in furnace	inches	.03	.32	.20
Draft at boiler damper	inches	.13	.89	. . . . .
Temperature of escaping gases	°F.	407	550	330
Total water fed to boiler	lbs.	1372862	594144	221682
Equivalent evaporation from and at 212°	lbs.	1437249	738024	242720
Equivalent evaporation from and at 212° per hour	lbs.	9981	30751	24272
Equivalent evaporation from and at 212° per square foot of heating surface per hour	lbs	2.34	5.10	4.67
Horse power developed	H. P.	289.3	891.3	703.5
Per cent of rated horse power developed	%	67.8	. . . . .	129.0
Total fuel fired	lbs.	142397	80088	20505
Per cent of moisture in fuel	%	1.77	12 12	4.30
Total dry fuel	lbs.	139877	70392	19623
Per cent of refuse by test	%	10.23	13.34	7.40
Total combustible	lbs.	125565	61002	18471
Dry fuel per square foot of grate surface per hour	lbs.	11.56	27.25	31.9
Flue gas analysis — CO_2	%	13.0	13.2	11.30
Flue gas analysis — O_2	%	5.9	5 7	8.60
Flue gas analysis — CO	%	.0	.1	.00
Proximate analysis dry coal — Volatile matter	%	33.42	32.69	16.74
Proximate analysis dry coal — Fixed carbon	%	56.30	55.53	77.39
Proximate analysis dry coal — Ash	%	10.28	11.78	5.87
B. t. u. per pound of dry fuel	B. t. u.	13332	13411	14346
Equivalent evaporation from and at 212° per pound of dry fuel	lbs.	10.28	10.48	12.37
Efficiency of boiler and furnace	%	74.83	75.86	83.67

* Two boilers.
† Integral economizer unit. Economizer contains 1433 square feet. Results are combined boiler and economizer results.

TESTS OF STIRLING BOILERS WITH VARIOUS FUELS

Plant		Dep't Public Service	B. & W. Co.	Detroit Edison Co.
Location		Toledo, O.	Barberton, O.	Detroit, Mich.
Boiler heating surface	sq. ft.	5019	11279	23650
Rated horse power	H. P.	502	1128	2365
Type of furnace		Underfeed	B.&W.chaingr	Underfeed
Grate surface	sq ft.	....	187	405
Fuel		Bitum. slack	Bitum. slack	Bitum. slack
Source or trade name		Ohio	Pittsburgh	RedJckt., W.Va.
Duration of test	hours	10	8	26.5
Steam pressure by gauge	lbs.	146	132	210
Temperature of feed water	°F.	151	109	188
Degrees of superheat	°F.	....	152	165.3
Factor of evaporation		1.1084	1.2352	1.1697
Blast under grates	inches	2.20	1.09	2.53
Draft in furnace	inches	.02	.16	.26
Draft at boiler damper	inches	.36	.97	.84
Temperature of escaping gases	°F.	465	624	651
Total water fed to boiler	lbs.	205152	499893	3907028
Equivalent evaporation from and at 212°	lbs.	228143	617468	4570051
Equivalent evaporation from and at 212° per hour	lbs.	22814	77184	172456
Equivalent evaporation from and at 212° per square foot of heating surface per hour	lbs.	4.55	6.84	7.29
Horse power developed	H. P.	662	2237.2	4999
Per cent of rated horse power developed	%	132.4	198.3	211.3
Total fuel fired	lbs.	23857	67292	424000
Per cent of moisture in fuel	%	6.20	3.50	1.9
Total dry fuel	lbs.	22378	64937	415944
Per cent of refuse by test	%	14.67	18.29	9.55
Total combustible	lbs.	19094	53060	376221
Dry fuel per square foot of grate surface per hour	lbs.	....	43.41	38.75
Flue gas analysis — CO_2	%	12.5	11.2	15.45
Flue gas analysis — O_2	%	6.6	8.3	3.86
Flue gas analysis — CO	%	.0	.0	0.17
Proximate analysis dry fuel — Volatile matter	%	32.71	31.35	33.48
Proximate analysis dry fuel — Fixed carbon	%	53.78	52.71	60.58
Proximate analysis dry fuel — Ash	%	13.81	15.94	5.94
B. t. u per pound of dry fuel	B. t u.	12888	12130	14061
Equivalent evaporation from and at 212° per pound of dry fuel	lbs.	10.20	9.51	10.99
Efficiency boiler and furnace	%	76.80	76.08	75.84

TESTS OF STIRLING BOILERS WITH VARIOUS FUELS

Plant	. .	Harvard Medical School	Wilkes-Barre Gas & Elec. Co	Boston Elevated Ry. Co.
Location	. .	Boston, Mass.	Wilk'Barre, Pa	Boston, Mass.
Boiler heating surface	sq. ft.	3188	2404	3500
Rated horse power	H. P.	319	240	350
Type of furnace	. .	Hand fired	Hand fired	Hand fired
Grate surface	sq. ft.	64	81	61
Fuel	. .	Bit. run of mine	Anthracite rice	Bit. run of mine
Source or trade name	. .	Pocahontas	Lehigh Valley	Pocahontas
Duration of test	hours	10	7.5	10
Steam pressure by gauge	lbs.	112	147.6	172
Temperature of feed water	°F.	75	34.6	167
Factor of evaporation	. .	1.1824	1.2285	1.0945
Blast under grates	inches	. . . . .	1.16	.22
Draft in furnace	inches	.15	.12	.08
Draft at boiler damper	inches	.40	.25	.30
Temperature of escaping gases	°F.	479	582	625
Total water fed to boiler	lbs.	92288	76577	133822
Equivalent evaporation from and at 212°	lbs.	109121	94075	146468
Equivalent evaporation from and at 212° per hour	lbs	10912	12543	14647
Equivalent evaporation from and at 212° per square foot of heating surface, per hour	lbs.	3.42	5.22	4.18
Horse power developed	H. P.	316.3	363.6	424.5
Per cent of rated horse power developed	%	99.1	151.5	121.3
Total fuel fired	lbs.	10647	12449	14200
Per cent of moisture in fuel	%	3.12	4.08	4.09
Total dry fuel	lbs.	10315	11941	13619
Per cent of refuse by test	%	8.62	22.1	8.21
Total combustible	lbs.	9426	9302	12501
Dry fuel per square foot of grate surface, per hour	lbs.	16.12	19.65	20.5
Flue gas analysis — CO_2	%	13.9	. . . . . .	13.6
Flue gas analysis — O_2	%	5.2	. . . . .	6.2
Flue gas analysis — CO	%	.1	. . . .	.4
Proximate analysis dry fuel — Volatile matter	%	. . . .	6.13	17.73
Proximate analysis dry fuel — Fixed carbon	%	. . . .	70.67	74.79
Proximate analysis dry fuel — Ash	%	. . . .	23.20	7.48
B. t. u. per pound of dry fuel	B. t. u	14381	11298	14637
Equivalent evaporation from and at 212° per pound of dry fuel	lbs	10.58	7.88	10.75
Efficiency of boiler and furnace	%	71.39	67.63	71.27

TESTS OF STIRLING BOILERS WITH VARIOUS FUELS

Plant		Pac. Lt & Pr. Co.	Southern Porto Rico Sugar Co	Ill. Steel Co.
Location		Los Angeles, Cal.	Porto Rico	So. Chi., Ill.
Boiler heating surface	sq. ft.	3288	4685	3612
Rated horse power	H. P.	329	468	361
Type of furnace		Oil*	Exten. bagasse	Blast fur. gas
Grate surface	sq. ft.	.....	23.4	.....
Fuel		Whittier, Cal. Oil	Bagasse	Blast fur. gas
Duration of test	hours	10	6	1.85
Steam pressure by gauge	lbs.	156	84	136.5
Temperature of feed water	°F.	63.7	155.1	44
Factor of evaporation		1.1992	1.0957	1.2175
Blast under grates	inches	.....	.24	4.2§
Draft in furnace	inches	.09	.13	.07
Draft at boiler damper	inches	.14	.35	.47
Temperature of escaping gases	°F.	454	539	743
Total water fed to boiler	lbs.	97722	95623	33650
Equivalent evaporation from and at 212°	lbs.	117188	104744	40969
Equivalent evaporation from and at 212° per hour	lbs.	11719	17462	22145
Equivalent evaporation from and at 212° per square foot of heating surface per hour	lbs.	3.56	3.73	6.13
Horse power developed	H. P.	339.7	506.1	641.9
Per cent of rated horse power developed	%	103.3	108.1	177.8
Total fuel fired	lbs.	7764	38952	.....
Per cent of moisture in fuel	%	1.06	44.70	.....
Total dry fuel	lbs.	7682	21540	.....
Dry fuel per square foot of grate surface per hour	lbs.	.....	153.4	.....
Flue gas analysis: CO_2	%	.....	13.2	20.1
Flue gas analysis: O_2	%	.....	6.9	4.0
Flue gas analysis: CO	%	.....	.1	.3
Ultimate analysis dry fuel: Carbon	%	86.02	44.12	Anal. ent'g. gas
Ultimate analysis dry fuel: Hydrogen	%	11.52	6.30	CO_2 — 12.5
Ultimate analysis dry fuel: Oxygen	%	1.45	47.47	O_2 — .0
Ultimate analysis dry fuel: Nitrogen	%	.25	0.41	CO — 25.8
Ultimate analysis dry fuel: Sulphur	%	.75	.....	H_2 — 2.5
Ultimate analysis dry fuel: Ash	%	.01†	1.70	CH_4 — .2
B. t. u. per pound of dry fuel	B. t. u.	18677	4088	.....
Equivalent evaporation from and at 212° per pound of dry fuel	lbs.	15.25	4.86	.....
Efficiency of boiler and furnace	%	79.23	63.85‡	.....

*Steam atomizing oil burners.
† Silt.
‡ Efficiency based on thermal value of bagasse as fired corrected for heat lost in evaporating and superheating its moisture. If correction extended to heat lost in burning H_2, efficiency would be 72.31%.
§ Pressure of entering gas.

TESTS OF STIRLING BOILERS WITH VARIOUS FUELS

Plant		The Babcock & Wilcox Co.		
Location		Bayonne, N. J.		
Boiler heating surface	sq. ft.	8500		
Rated horse power	H. P.	850		
Type of furnace		Oil—B. & W. Mechanical Oil Burners		
Fuel		Mexican Oil—Approx. 15° Eng.		
Duration of test	hours	3.0	3.0	3.5
Steam pressure by gauge	lbs.	174.9	179.8	183.0
Temperature of feed water	°F.	74	74	72
Degree of superheat	°F.	69.9	52.2	43.0
Factor of evaporation		1.2341	1.2241	1.2214
Draft in furnace	inches	.19	.19	51
Draft at boiler damper	inches	.21	.30	.90
Temperature of oil at burners	°F.	249.5	248.5	234.3
Pressure of oil at burners	lbs.	161.5	200.0	210.0
Temperature of escaping gases	°F.	451	512	575
Total water fed to boiler	lbs.	76731	109515	176478
Equivalent evaporation from and at 212°	lbs.	94695	134112	215548
Equivalent evaporation from and at 212° per hour	lbs.	31565	44704	61585
Equivalent evaporation from and at 212° per square foot of heating surface per hour	lbs.	3.73	5.26	7.25
Horse power developed	H. P.	914.9	1295.8	1785.1
Per cent of rated horse power developed	%	107.6	152.4	210.0
Total fuel fired	lbs.	6174	8923	14882
Flue gas analysis — CO_2	%	13.2	12.2	13.9
Flue gas analysis — O_2	%	3.7	4.7	2.3
Flue gas analysis — CO	%	.0	.0	0
Ultimate fuel analysis — Carbon	%	84.96	84.96	84.88
Ultimate fuel analysis — Hydrogen	%	11.28	11.28	10.00
Ultimate fuel analysis — Oxygen and nitrogen	%	0.86	0.86	1.31
Ultimate fuel analysis — Sulphur	%	2.90	2.90	3.81
B. t. u. per pound of fuel	B.t.u.	18125	17989	18201
Equivalent evaporation from and at 212° per pound of fuel	lbs.	15.34	15.04	14.49
Efficiency of boiler and furnace	%	82.13	81.13	77.25

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